APRIL 1960

NUCLEONICS

APPLIED RADIATION • ATOMIC POWER • NUCLEAR ENGINEERING

AEC PUTS TOGETHER A LONG-RANGE POWER REACTOR PROGRAM

NUCLEONICS DIGESTS IT FOR YOU... PAGE 71

A McGraw-Hill Publication • One Dollar

NOW . . . DATA PRINT-OUT IN MANY FLEXIBLE MODES OF OPERATION!

High-Speed Scaler and Electronic Timer

OPERATING MODES

- **Preset Count:** 15 settings from 10 to 500,000 counts.
- **Preset Time:** 18 settings from 0.1 to 50,000 seconds.
- **Combined Preset Time & Count:** any of the time or count settings may be used simultaneously with the system stopping when the first preset event occurs.
- **Data Print-Out:** both scaler and timer provide "staircase" outputs. Time, counts, or both may be printed out or code punched on cards or tape.
- **Automatic Recycling:** The system will recycle automatically, if desired, following occurrence of a preset event and data print-out. In this case, print-out can be cumulative or destructive. Both print-out and automatic recycling can be used in any mode of operation.

These units are not only highly flexible but are also of the fine research quality typical of all Hamner Instruments. Scaler and Timer may be used together to provide the operational modes listed above. They may also be used independently.

N-803 TIMER

Stability: 100 CPS, crystal controlled.
Preset Time: 18 ranges from 0.1 sec. to 50,000 secs
Elapsed Time: to 10,000 secs.
Panel Dimension: 3½" height for standard Rack Mounting.

N-276 SCALER

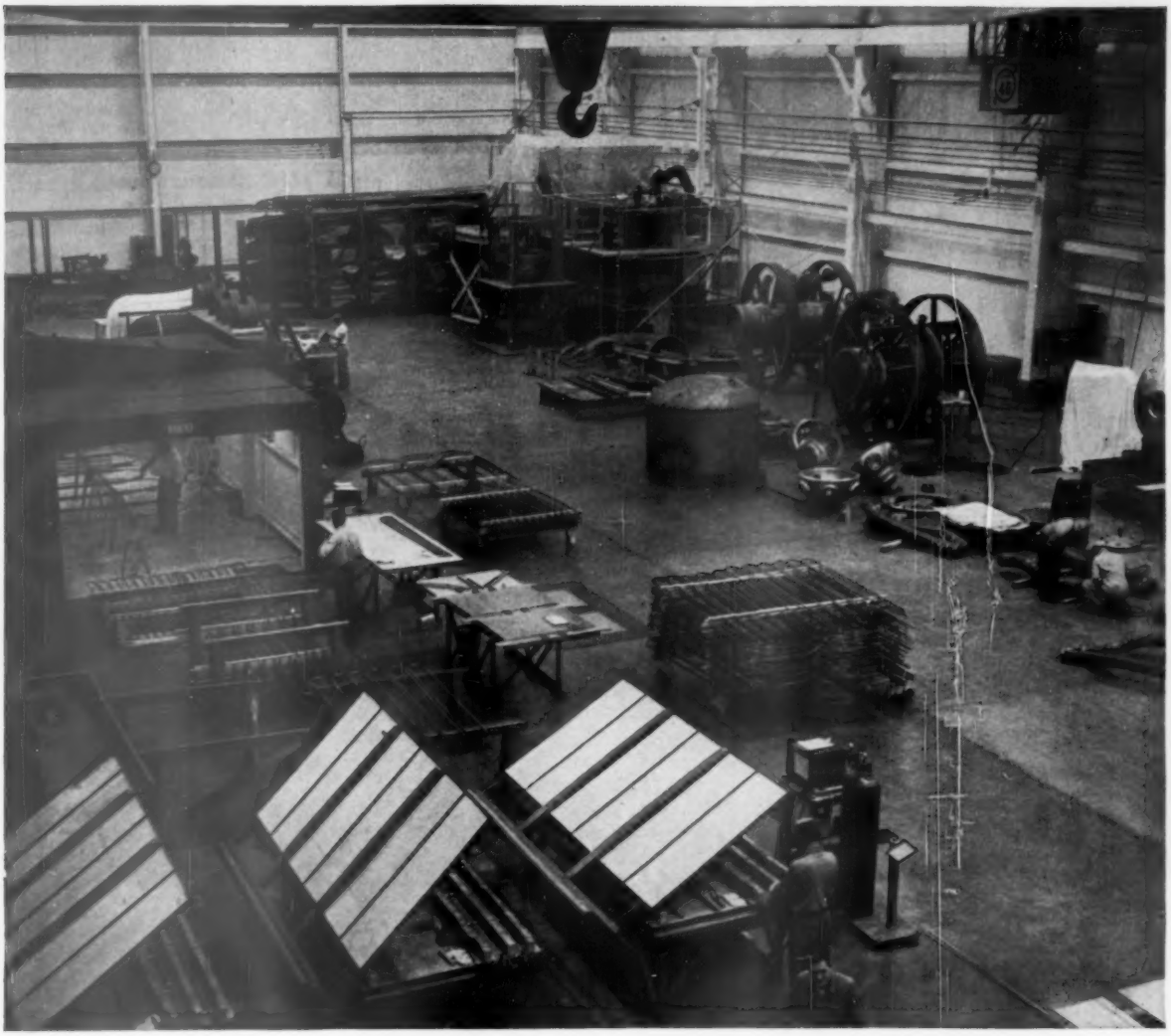
Pulse Pair Resolution: better than 1 us
Continuous Repetition Rate: 1 megacycle.
Indication: 6 electronic decades. (7 in model N-277)
Preset Time:
Combined Preset Time and Count:
Preset Count:
As previously described
Internal Calibration: 60 cycle
Input Sensitivity: 4V minimum, + or — by front panel switch
Panel Dimension: 3½" height, for standard Rack Mounting.

See the N-276 and N-803 Timer plus other completely new Hamner Instruments at the **Atomic Exposition, Space #338.** April 4 - 7 incl., New York Coliseum.

For Additional Information Please Write:

Hamner

Hamner Electronics Co., Inc.
Department 4, P.O. Box 531, Princeton, New Jersey, PEnnington 7-1320



Assembly Line For Nuclear Boilers

The careful control required in the fabrication of nuclear boilers has led to the construction of a 22,000 sq. ft. "clean room" at B&W's Barberton, Ohio plant. Here the most modern equipment is housed in an air conditioned building where hospital type conditions assure the highest quality component possible.

B&W nuclear components have been or are being supplied to more than 70 major research or power reactors throughout the world. This experience is available to you . . . your engineering staff . . . your consultants. The Babcock & Wilcox Company, Boiler Division, Barberton, Ohio.

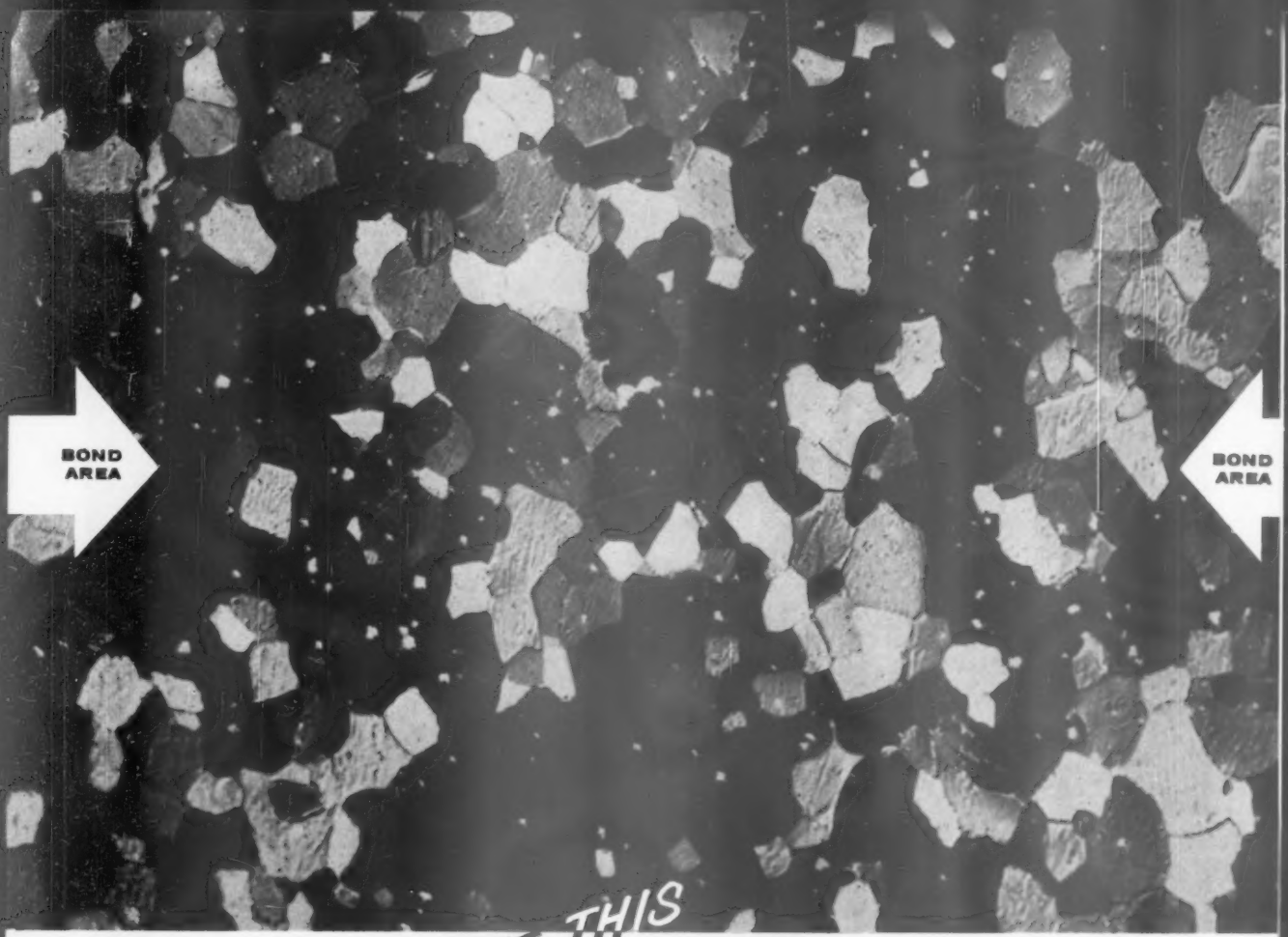
B&W

THE BABCOCK & WILCOX COMPANY

BOILER DIVISION

NC-110

Complete nuclear systems, cores, components, fuel elements, nuclear research and development



LIKE THIS

BONDS ARE OUR BUSINESS

A high-integrity metallurgical bond between fuel and cladding is your best guarantee against void-induced fuel cladding failures.

Element processing that eliminates bond line defects and exhibits grain growth across interfaces can enhance fuel life and reactor performance.

M & C Nuclear's superior experience and technical knowledge in bonding metals is widely recognized in the nuclear industry. Elements bonded by hot rolling, cold rolling, coextrusion, brazing, welding, and pressing have been made in production quantities. We are also equipped to check the integrity of our bonds by metallographic examination and the nondestructive methods such as radiography and ultrasonic testing.

Our bonding skill is another reason that M & C Nuclear fuel elements contribute to efficient reactor operations. Let us confer with you in an early stage of your reactor design project to assure the greatest economies in fuel element utilization.

Another example of M & C's technical skills in the nuclear industry.

TEXAS INSTRUMENTS
INCORPORATED
M&C NUCLEAR, INC.
(A SUBSIDIARY)
P. O. BOX 898 • ATTLEBORO, MASSACHUSETTS, U. S. A.

The World's Largest Privately Owned Facility Designed Specifically for Fabrication-Development and Production of Fuel Elements, Core Components and Complete Cores.

NUCLEONICS

APPLIED RADIATION • ATOMIC POWER • NUCLEAR ENGINEERING

APRIL 1960

VOLUME 18 NUMBER 4

FEATURE ARTICLES

60 Irradiation Reactions in Hydrocarbon Gases
FREDERICK W. LAMPE

66 Data Sheet No. 37—Conduction Heat-Flow Transients
JOSEPH S. HUCKS and A. L. GAINES

68 Uranium Isotope Separation by Nozzles
MYRON LEVOY

71 AEC Puts Together A Long-Range Power-Reactor Program

72 Nuclear Power Fast Becoming Economic

74 Problems and Programs for the Eight Major Concepts

82 Fuel Developments Key to Reactor Progress

INSTRUMENTATION & MEASUREMENTS

84 Automatic Film-Badge Reader
MACK WILHELMSEN, DeRAY PARKER, ROBERT W. COULTER and PAUL R. BOREN

90 Transistor Pulse Generator
EDWIN GORDY and GEORGE SIEBER

92 New Glass Dosimeter Is Less Energy-Dependent
R. J. GINTHER and J. H. SCHULMAN

NUCLEAR ENGINEERING

96 A Closer Look at the *Real* KIWI-A

98 Calibration of ORNL Lid-Tank Fission Plates
WHITTIE J. McCOOL and D. R. OTIS

102 Bacterial "Infection" of the Omega West Reactor
ERIC B. FOWLER, C. W. CHRISTENSON, EDWARD T. JURNEY and WILLIAM D. SCHAFER

APPLIED RADIATION

108 Complementary Effects of Heat and Radiation on Food Microorganisms
LLOYD L. KEMPE

DEPARTMENTS

NUCLEAR REACTIONS 6
NEWS OF THE MONTH 21
EDITORIAL 59
APPLIED RADIATION 106
BOOKS 120
PRODUCTS AND MATERIALS 124
INDUSTRY NOTES 134
NUCLEAR CAMPUS 135
NEWSMAKERS 136
NUCLEAR CALENDAR 138

COMING FEATURES

NEXT MONTH

Scintillation-Counting Symposium
Gas-Cooled-Reactor Symposium
Chemical Protection
Sodium-Heated Steam Generators

LATER MONTHS

Accelerator Neutron Sources
Radioactivity in Water Reactors
Radiation Effects in PVC
Low-Cost Accelerators

Jerome D. Luntz, Editor and Publisher

Daniel I. Cooper, Managing Editor

TECHNICAL STAFF

Thomas L. Cramer, Associate Editor
R. Hobart Ellis, Jr., Associate Editor
Harold L. Davis, Associate Editor
James J. Dutton, Associate Editor

NEWS STAFF

John E. Kenton, News Editor
Robert E. L. Adamson, Assistant News Editor

John Wilhelm, Manager, News Bureaus
Washington—G. B. Bryant, Jr., Chief, Richard A. Smith; London—John Shinn, John Tunstall; Paris—Robert E. Farrell, Arthur L. Erikson; Bonn—Morrie Helitzer, Silke Brueckler; Moscow—Ernest Conine; Tokyo—Sol Sanders; Rio de Janeiro—Jerry Gingell; Mexico City—Peter Weaver; Melbourne—Alicja Grobtuch; Beirut—O. M. Marashian; Brussels—A. P. L. Gordon; Bombay—Sharokh Sabavala; Zurich—Raymond Shah; Johannesburg—Norman Herd; Milan—Gene DiRaimondo; Stockholm—Curt Agren; Vienna—F. H. Baer

PRESENTATION STAFF

Tom Howland, Jr., Art Director
Carol Williamson, Production Editor

Keith Henney, Consulting Editor

•

Philip H. Hubbard, Jr.
Advertising Sales Manager

R. S. Quint, Buyers' Guide Manager
George Pomeroy, Classified Advertising Mgr.
Frederic Stewart, Promotion Manager
James F. O'Brien, Business Manager
Hugh J. Quinn, Circulation Manager
James H. Thomas, Market Research Manager

ADVERTISING STAFF

Donald J. Cassidy, New York
Frederick R. Whitmore, Boston
Warren H. Gardner, W. J. Boyle, Jr., Philadelphia
Willis T. Smith, Chicago
Paul T. Fegley, Cleveland
David M. Watson, Pittsburgh
T. H. Carmody, R. C. Alcorn, San Francisco
D. A. McMillan, M. W. Freeman, Los Angeles
D. Billian, M. Miller, Atlanta
Robert T. Wood, Dallas
Jack Patten, Denver
E. E. Schirmer, London
Stanley Kimes, Frankfurt
Michael R. Zeynel, Geneva

...about NUCLEONICS

Why Not "We"?

Among the technical articles in this issue is at least one which we editors feel would be improved by freer use of the personal pronoun in first-person plural, nominative case—commonly referred to as "we." It is most unfortunate that many scientists and engineers feel it wrong to use active voice when referring to their own actions in conducting an experiment or designing a reactor. It is a lot more to the point to say, "We decided to heat the vessel," than to say, "The decision was made to elevate the temperature of the vessel." The point we are making is not just a grammatical one—with more direct expression comes clearer, more forceful thinking.

Some of the blame must be placed with freshman-laboratory instructors, who, as we recall, required us to write reports in a style that was almost as weak as the results we reported. But just as one grows beyond the measurement of a meter stick so we should outgrow stylistic bonds that leave one talking as if the scientific world had no people in it but only experiments that "are performed."

We all face the problem of assimilating ever-increasing amounts of scientific and technical information. One way to ease the problem is to write more clearly and concisely. We on NUCLEONICS try to do that for you. It will help us if the scientific community overcomes its prejudice against personal pronouns. Why not say "We"? Why not, O brave architects of the nuclear future, even dare to say "I"?

Ten-Year Program—For You

The Atomic Energy Commission has just released and formally published its Civilian Power Reactor Program—and NUCLEONICS has hastened to bring a report (page 71) on the program to you. This latest step in our continuing coverage of the Ten Year Program— as the AEC plan is more commonly called—caps the stage-by-stage reports that have been carried out in our news section as the program evolved.

AEC has set forth not only the anticipated improvement in the economics of nuclear power but also the principal technical problems that need to be overcome and the funding that AEC intends to provide to overcome those problems. Thus one has a kind of master plan for the future. Of course, this planning is done with full recognition of its own limitations; nonetheless it provides for each of us (and for *you*) a clearer picture of where we go from here.

Certainly for the editors of NUCLEONICS the program report has provided important clues to subjects that need to be covered in our pages in the months and years ahead.

Ahhhh Choo!

A new reactor hazard is upon us—bacterial infection. Don't panic though—it's not as serious as jammed control rods or insufficient negative reactivity. But bacterial infection *did* play a part in some difficulties that forced the shutdown of Los Alamos' Omega West reactor a couple of summers ago. The full story is told on p. 102.

Aside from problems of reactor operation, the Los Alamos story raises an intriguing question for the radiation biologist—how does the *Pseudomonas* bacterium survive the intense radiation environment?

—*The Editors*

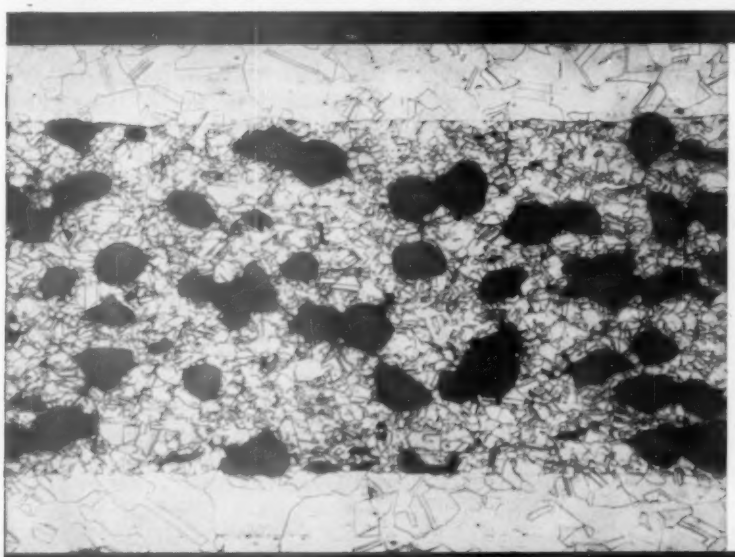
A McGRAW-HILL PUBLICATION

NUCLEONICS (with which are consolidated "Atomic Power" and "Atomic Engineering"), April, 1960, Vol. 18, No. 4. Published monthly by the McGraw-Hill Publishing Co., Inc., James H. McGraw (1860–1948), founder. **Executive, Editorial, Circulation and Advertising Offices,** McGraw-Hill Building, 330 W. 42nd Street, N. Y. 36, N. Y. Publication Office, 212 East York St., York, Pa. See panel below for directions regarding subscriptions or changes of address. **Officers of the Publications Division:** Nelson L. Bond, President; Shelton Fisher, Wallace F. Traendly, Senior Vice Presidents; John R. Callaham, Vice President and Editorial Director; Joseph H. Allen, Vice President and Director of Advertising Sales; A. R. Venezian, Vice President and Circulation Coordinator. **Officers of the Corporation:** Donald C. McGraw, President; Joseph A. Gerardi, Hugh J. Kelly, Harry L. Waddell, Executive Vice Presidents; L. Keith Goodrich, Vice President and Treasurer; John J. Cooke, Secretary. United States Subscription rate for individuals in the field of publication $8 per year; $12 for 2 years; $16 for 3 years. Canada, other Western Hemisphere countries, and the Philippines, $10 for 1 year; $16 for 2 years; $20 for 3 years; all other countries, $15 for 1 year; $25 for 2 years; $30 for 3 years. Single copy prices: United States, United States possessions, and Canada, $1; elsewhere, $2. Second-class mail privileges authorized at York, Pa. Printed in U. S. A. Title registered in U. S. Patent Office. © Copyright 1960 McGraw-Hill Publishing Co., all rights reserved.

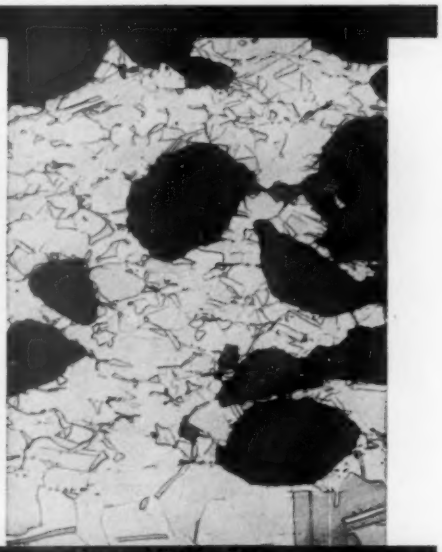
SUBSCRIPTIONS. Send subscription correspondence and change of address to Fulfillment Manager, NUCLEONICS, 330 W. 42nd Street, New York 36, N. Y. Allow one month for change of address, giving old as well as new address, and including postal zone number, if any. If possible, enclose an address label from a recent issue of the magazine. Please allow one month for change to become effective. Subscriptions are solicited from individuals engaged in the design, development and use of atomic power, nuclear engineering and applied radiation. Position and company connection must be indicated on subscription orders.

Postmaster. Please send form 3579 to NUCLEONICS, 330 W. 42nd St., N. Y. 36, N. Y.

FUEL ELEMENT CORES ARE POWDER-ROLLED FOR MAXIMUM BURN-UP



"... uniform dispersal ... minimum break-up and stringering."



"... close crystalline bonding ..."

"... special rolling mill ..."

Martin is now producing stainless steel-uranium dioxide fuel elements with virtually no oxide break-up or stringering, and with excellent control of fuel location. Prototype elements have achieved up to 42% burn-up, and even better performance can be expected with improved production elements.

In this new process, the finely powdered stainless steel-uranium dioxide mixture is passed through a special rolling mill and formed into a ribbon of near-final thickness before being enclosed in its stainless steel cladding. Subsequent fabrication to finished dimensions increases the length of the fuel core by only ½ compared with elongation ratios of approximately 7 to 1 in conventional practice.

The 100X longitudinal cross-section photomicrograph above shows the uniform dispersal of uranium dioxide grains throughout the core with minimum break-up and stringering. The 250X enlargement at the right shows the close crystalline bonding between cladding and core achieved in this process.

The powder rolling technique is used for both flat-plate and tubular fuel elements. It is currently being used to produce elements for Martin's PM-1 air-transportable reactor being developed for the AEC and soon to become operational at a remote Air Force station.

Martin is also producing ceramic rod-type elements for the Allis-Chalmers commercial power station at Elk River, Minnesota, and aluminum flat-plate elements for AMF Atomics. Martin recently produced the SPERT-2 core for Phillips Petroleum, and foil-type criticality elements for the ERDL program, and for the University of California.

Dr. Harry P. Kling, Manager-Nuclear Components

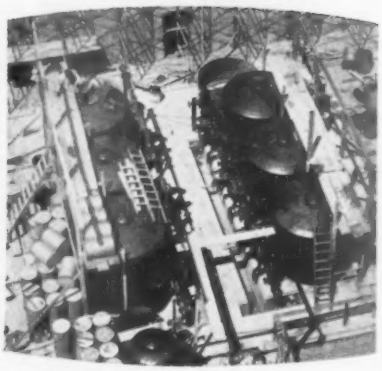
MARTIN

At 00h 00m 01s GMT April 1, 1960 Martin logged it's 490,932,000th mile of space flight.

PATHWAYS OF A PIONEER

ILLCO-WAY DESIGNERS AND BUILDERS

MODERN EQUIPMENT FOR ionXchange



This picture was taken in *1943* of a Continuous *600 gpm* IonXchanger during installation at a midwestern chemical plant. The tanks are shown being loaded with ionXchange resins.

Blazing the Trail for De-I Developments

When the photograph above was made, IWT already had well over 50 large industrial ionXchangers in successful operation — yet ion-exchange in those days was still considered a "new and untried" process! Many of these pioneering IWT installations are *in use today*, and most of the early users of IWT ionXchange have *added to* and *modernized* their equipment as new developments became available.

Even today IWT is still pioneering — adding to its great stock of knowledge in this specialized field, designing and building up-to-date ionXchangers of all types and sizes for application to a wide variety of processes as well as all kinds of water-treatment, experimenting with and carefully testing new ionXchange uses, and constantly improving existing designs.

THIS EXPERIENCE CAN MEAN A LOT TO YOU

If you need pure water for high-pressure boiler make-up or process use, or if you are considering the use of ion-exchange for purification or concentration of chemical products, be sure to take advantage of IWT pioneering experience and specialized knowledge. *Call your IWT representative.*

ILLINOIS WATER TREATMENT CO.
840 CEDAR ST., ROCKFORD, ILLINOIS
NEW YORK OFFICE: 141 E. 44th St., New York 17, N.Y.
CANADIAN DIST.: Pumps & Softeners, Ltd., London, Ont.

NUCLEAR REACTIONS

Pitfall for Pittman

DEAR SIR:

The December issue of NUCLEONICS contained on p. 21 a very concise and useful summation of Dr. Frank Pittman's talk at the AIF Annual Meeting in Washington. Potential cost estimates for the gas-cooled enriched-uranium concept (among others) were given.

Many of Dr. Pittman's listeners and subsequent readers may have assumed that the gas-cooled reactor figures were based on a study of both the Allis-Chalmers–Kaiser Oak Ridge Experimental Gas-Cooled Reactor and the Peach Bottom Atomic Power Station, which employs General Dynamics' HTGR reactor design. This is not the case. Correspondence with the AEC has established the fact that the figures quoted were based solely on the Oak Ridge gas-cooled reactor study and do not reflect the AEC's estimate of the potential of the more advanced High-Temperature Gas-Cooled Reactor design.

The HTGR prototype inaugurates a new class of reactors. It is our strong belief that HTGR plants in sizes of 150-300 Mw(e) can be built and operated to be competitive with conventional power in many parts of the United States.

—C. A. ROLANDER, JR., VICE PRESIDENT
General Atomic
San Diego 12, California

EDITOR'S NOTE: Mr. Rolander's remarks continue to hold for the final 10-year program reviewed in this issue (p. 71).

National Labs

DEAR SIR:

Thank you for the opportunity to review the March NUCLEONICS editorial concerning the national laboratories.

The basic origin of the discussions relating to the future role of the national laboratories appears to stem from concern that budgetary adjustments may threaten the full utilization of the country's industrial and national laboratories. At a time when the nation is being called upon to increase its over-all technological capabilities, this seems to be a rather incongruous situation.

It has always been my opinion that the national laboratories represent a valuable asset which should continue to play a significant role in the nation's atomic energy program. Private industry in the past decade has also developed a major capacity for nuclear power development. It is in the division of effort between these two partners of the U. S. nuclear capability that sound long-range planning must be accomplished.

I believe that the national laboratories should concentrate their efforts in the areas of basic nuclear science and pioneering technology. As in the past, these laboratories could be the principal source of the major scientific and technical "breakthroughs" in atomic energy.

In those areas where the feasibility of the technology and basic scientific information has been established, the private industrial laboratories could carry out the reactor and engineering development. The burden of introducing the new technologies to practical application would thus be carried by industry. There would be some necessary areas of overlap in these functions which could provide the opportunity for both groups to maintain the proper perspective toward the applied effort and the fundamental research.

The technical strength of the country as represented by both the industrial and national laboratories can be most efficiently utilized by planning and budgetary recognition of these complementary roles.

—CHAUNCEY STARR, VICE PRESIDENT
North American Aviation, Inc.
Canoga Park, California

DEAR SIR:

I believe that your editorial on the National Laboratories states fairly the belief of thoughtful people regarding the problem which it discusses. A clear, long-term policy is very desirable if we are to meet the two important objectives: that of maintaining the strength of the laboratories while at the same time truly fostering the development of a strong nuclear industry. The laboratories have certainly earned sufficient support so that their competence can and will be maintained. However, I believe that it will be very difficult for them to work in such a way as to truly foster the nuclear industry without continued expression from industry of its needs in the process. Hence, we must have some mechanism which continually injects industry's own ideas as to

what industry needs into the over-all policy determination of the Atomic Energy Commission in this area.

—F. K. McCune, Vice President
Engineering Services
General Electric Company
New York, N. Y.

Dear Sir:

The discussion of the role of the national laboratories in your March editorial presents clearly the objectives and basic philosophy which we at Argonne National Laboratory have used as our guiding principles in our operations over the past twelve years. May I express my appreciation for your statement of the situation as seen by an impartial outsider. It is encouraging to find so much in common between your analysis of the national need for laboratories such as ours and the basic principles we have striven to follow.

There appears to be general agreement that certain areas of research are of principal concern to the universities and that certain areas of development become clearly the responsibility of industry. There also seem to be certain areas both in research and development on which there is general agreement that the national laboratories have unique capabilities. It is in those areas in which the responsibilities of the laboratories overlap those of the universities or those of industry that the disagreements arise. At Argonne National Laboratory we have been attempting to limit these areas of overlap of interest just as stringently as we can and still achieve our approved program objectives. We believe that the actual record of our willingness to cooperate both with universities and with industry has been good and speaks for itself. The experience at Argonne over the past decade is that the existence of overlapping interests, although it brings problems, is, in the over-all balance sheet, of great value. The active collaboration between Argonne and the universities and between Argonne and industry can be, and in many cases has proved to be, of mutual value. Such cooperation rapidly disappears as the number of subjects of common interest diminishes. I believe that industry owes a real debt to the national laboratories for their contributions and I am convinced that if a vital cooperative program is maintained, industry will continue to profit from the accomplishments of the laboratories.

We at Argonne agree that the Laboratory should not be in direct competition with industry in doing those things

(*Continued on page 114*)

Now . . . from VICTOREEN
a complete line of

electrometers

✓GREATER STABILITY
✓WIDER DYNAMIC RANGE

VTE SERIES LINEAR

ECONOMICAL . . . VTE-0. 9 ranges from 10^{-3} to 11^{-11} amperes.

PRACTICAL . . . VTE-1. Same as VTE-0 but with bucking supply current and choice of time constants.

SENSITIVE . . . VTE-2. 30 ranges from 10^{-3} to 2×10^{-13} amperes.

2VTE-0 DUAL LINEAR

2LE-1 Dual Log.
2 units, log or linear, on same chassis.

2VTE-0D LINEAR DUAL DIFFERENTIAL

2LE-1D Log Dual Differential.
Built-in differential indication from two low-current inputs.

The Tullamore electrometer line, by Victoreen, comprises a complete range of stable, low-cost instruments manufactured to the highest precision standards and incorporating all the most desirable features. A-135A

Write for literature, giving model number in which interested.

The Victoreen Instrument Company
5806 Hough Avenue • Cleveland 3, Ohio
Export Department, 135 Liberty Street, New York 6, N. Y.
Cable: TRILRUSH, New York
WORLD'S FIRST NUCLEAR COMPANY

General Mills "Muscle-Man" with a Gentle Touch

Photo courtesy of Curtiss-Wright Corporation, Research Division, Quehanna, Pennsylvania

At Curtiss-Wright, this General Mills Mechanical Arm helps solve remote handling problems

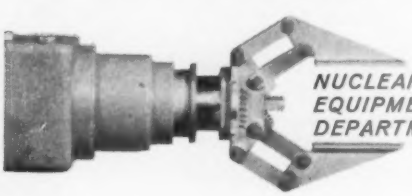
At Curtiss-Wright Nuclear Materials Laboratory —as in almost all other major atomic installations in America—the General Mills Mechanical Arm solves remote handling problems. It lifts great weights with ease, yet handles fragile material safely. Each of three models of the Mechanical Arm is adaptable to nearly any installation requirement.

Our Nuclear Equipment Department provides facilities planning services and a full line of remotely controlled handling devices: heavy duty and underwater manipulators; power tools and accessories; crane hoists; boom or wall mounted manipulators; mobile remote handlers; fuel handlers; reactor service and maintenance equipment; and many other standard and custom designed products.

If your operation involves remote handling, you'll want to contact the Nuclear Equipment Department of General Mills. If we have not already built remote handling devices which will satisfy your requirements, we have the experience and know-how to design custom equipment to suit your needs.

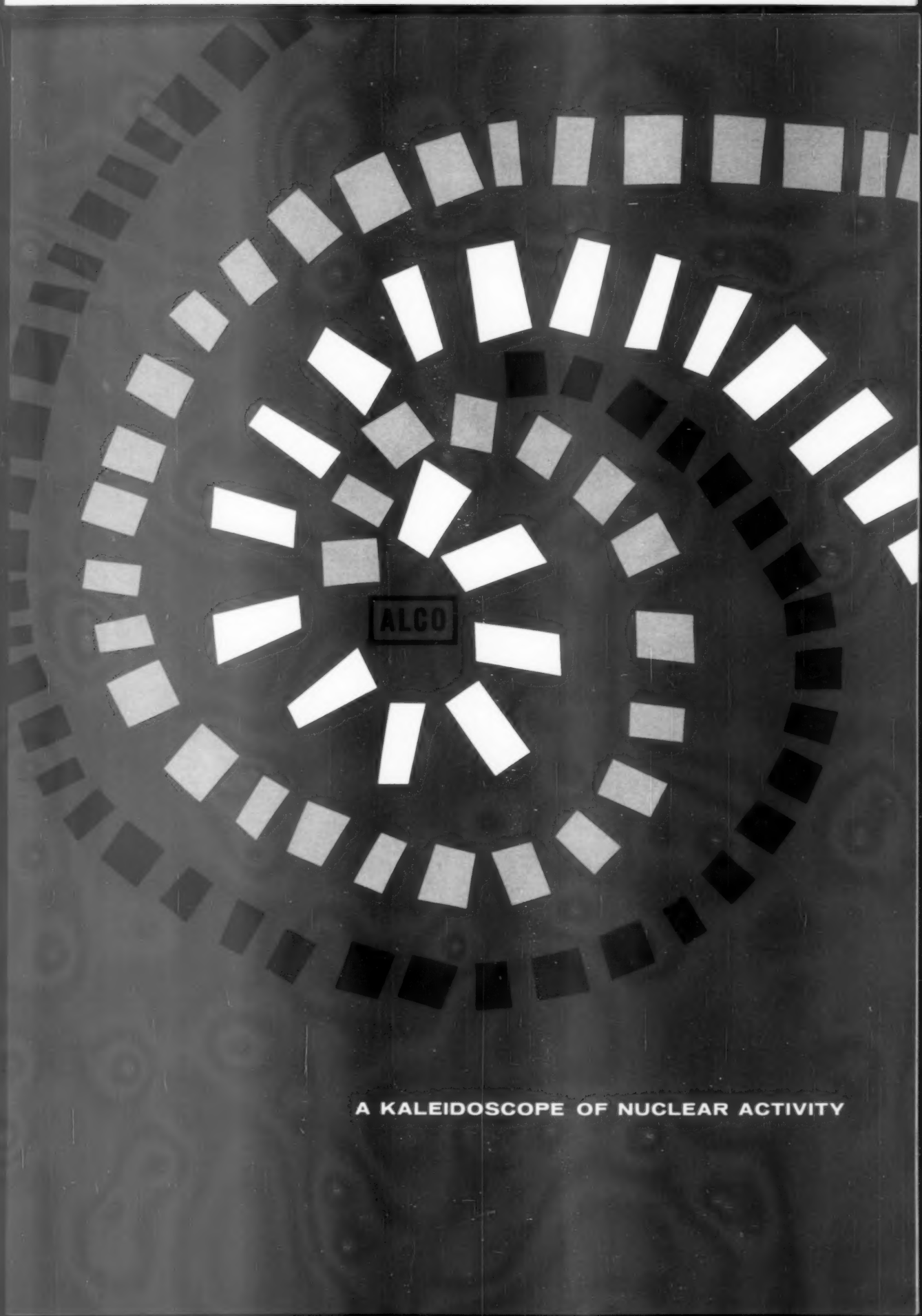
Write for our five new engineering bulletins:

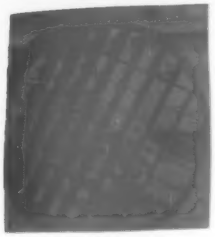
Nuclear Equipment Department
Mechanical Division of General Mills
419 North 5th Street
Minneapolis 1, Minnesota

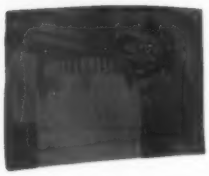


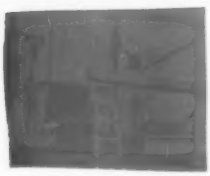
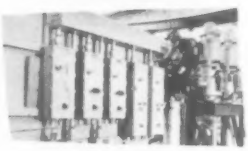
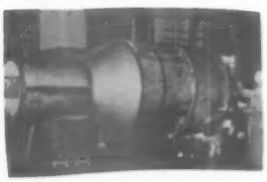
First In Remote Handling
MECHANICAL DIVISION
Minneapolis, Minnesota

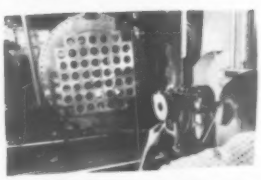
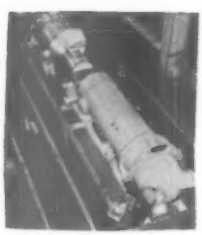
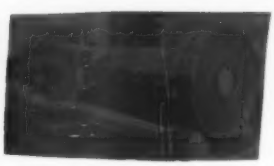
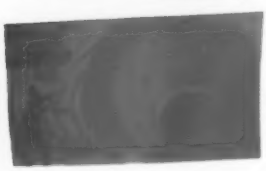
General Mills

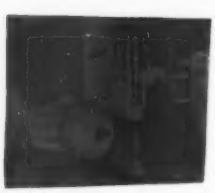
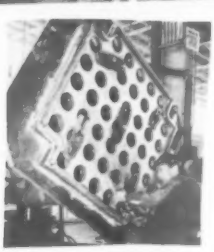

ALCO
A KALEIDOSCOPE OF NUCLEAR ACTIVITY

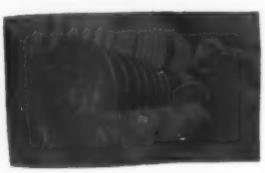
RADIATION




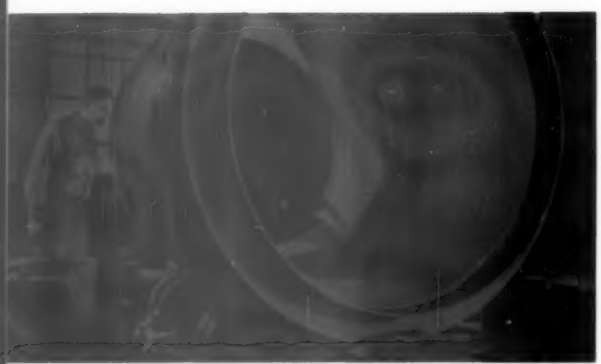




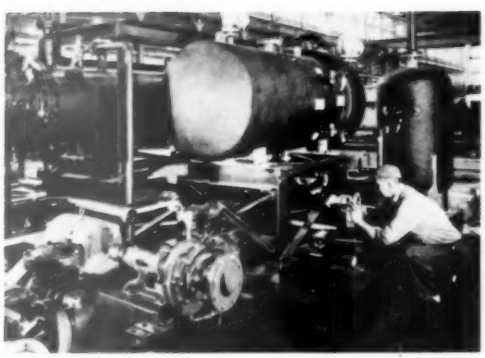





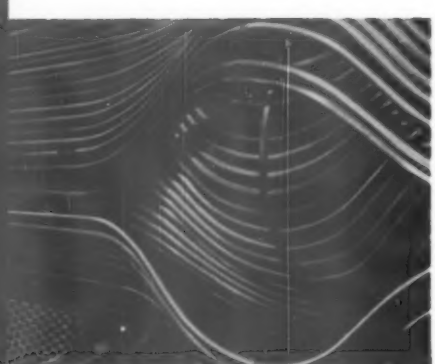





ALCO'S NUCLEAR CAPABILITY...







. . . REFLECTED BY THOUSANDS OF PROBLEMS SOLVED, HUNDREDS OF COMPONENTS DESIGNED AND BUILT FOR 9 OUT OF 10 MAJOR U.S. REACTORS

When you evaluate ALCO's nuclear capability, you must look at many things. For ALCO's capability is the sum total of experience gained in component design and manufacture for practically every U.S. power reactor.

You must look at men and machines...engineers who work a little faster, a little more effectively because of their background in nuclear-design problems...quality control people who are experienced and equipped in advanced techniques of inspection...production personnel with the latest machinery at their disposal, including a computer center for programming and production scheduling.

Look at what these attributes have led to. Heat exchangers with sine-wave tubes... methods of welding and fabricating alloys like Inconel, zirconium and stainless...complex shock-loading and transient-temperature stress analysis on data-processing equipment...an image electrical analogy method of determining heat flow paths and temperature distribution in complex configurations...just a few among many.

Men with experience and know-how like this ...equipped with the tools and backing for the job...these are what make up ALCO's kaleidoscope of nuclear activity.

These are the reasons why ALCO can serve your nuclear component needs best.

MAJOR NUCLEAR PROJECTS USING ALCO COMPONENTS

(Not including components manufactured for ALCO-built nuclear power plants)

NAVAL NUCLEAR POWER PLANTS

S2W (Nautilus) Westinghouse, U.S. Navy	Emergency coolers (hard tank) Regenerative exchanger Non-regenerative exchanger Pressurizing heat exchanger
S2WA (Sea Wolf—Conversion) Westinghouse, U.S. Navy	Regenerative exchanger Non-regenerative exchanger
S4G (Prototype and Submarine) General Electric, U.S. Navy	Emergency condensers
C1W (Cruiser) Westinghouse, U.S. Navy	Regenerative exchangers Non-regenerative exchangers Pressurizers
A2W (Aircraft Carrier) Westinghouse, U.S. Navy, Metals & Controls Nuclear	Regenerative exchanger Non-regenerative exchanger Core components
S5W (Submarines) Westinghouse, U.S. Navy	Regenerative exchanger Non-regenerative exchanger
S2C (Submarine) Combustion Engrg., AEC U.S. Navy	Pressurizers
D2G (Destroyer) KAPL, AEC, U.S. Navy Olin Mathieson	Pressurizers Regenerative exchangers Non-regenerative exchangers Core components
HMS Dreadnaught (British Submarine) Westinghouse, Rolls Royce, Royal Navy	Emergency cooler Fresh water-sea water exchangers

EXPERIMENTAL PROTOTYPE POWER PLANT REACTOR SYSTEMS

EBR-1 (Experimental Breeder Reactor) Argonne National Laboratories	Intermediate liquid metal heat exchanger
EBWR (Experimental Boiling Water Reactor) Argonne National Laboratories	Control-rod drives
SRE (Sodium Reactor Experiment) Atomics International	Primary sodium loop exchangers Secondary sodium-loop air blast coolers, main and auxiliary
ALPR (Argonne Low Power Reactor) Argonne National Laboratory	Control rod drives
S1W (Nautilus Prototype) National Reactor Test Station Westinghouse, U.S. Navy	Carbon steel steam generator Emergency coolers (hard tank) Regenerative exchanger Non-regenerative exchanger Pressurizing tank—effluent tank heat exchanger Purification exchangers
A1W (Aircraft Carrier Prototype) Westinghouse, AEC, U.S. Navy	Steam generators
S1C (Submarine Prototype) Combustion Engrg., AEC, U.S. Navy	Pressurizers
D1G (Destroyer Prototype) KAPL, AEC, U.S. Navy, Olin Mathieson	Pressurizers Regenerative exchangers Non-regenerative exchangers Core components
S3G (Submarine Prototype) General Electric, U.S. Navy	Emergency condensers
SAR Critical Assembly General Electric-Knolls Atomic Power Laboratory	Pressure vessel
CP-5 (Research Reactor) Argonne National Laboratory	D_2O cooler

COMMERCIAL NUCLEAR POWER PLANTS

PWR (Pressurized Water Reactor) Westinghouse, Duquesne Power & Light	Regenerative exchanger Non-regenerative exchanger
VBWR (Vallecitos Boiling Water Reactor) General Electric	Emergency condenser
PRDC (Enrico Fermi Station) Power Reactor Development Corp.	Intermediate sodium exchangers
BTR (Belgium Thermal Reactor) Syndicat d'Etude del 'Energie Nucleare, Westinghouse	Pressurizer
RCPA (Elk River Reactor Project) Allis-Chalmers Mfg. Co. Sargent & Lundy	Start-up heater Regenerative exchanger Non-regenerative exchanger Shield cooler Control rod drives Decay heat cooler
ORC (City of Piqua Reactor Project) Atomics International	Steam generator and superheater

ALCO-BUILT NUCLEAR PLANTS

SM-1, 10 MW

SM-1A, 20 MW

PM-2A, 10 MW

ALCO NUCLEAR COMPONENTS

ALCO PRODUCTS, INC.

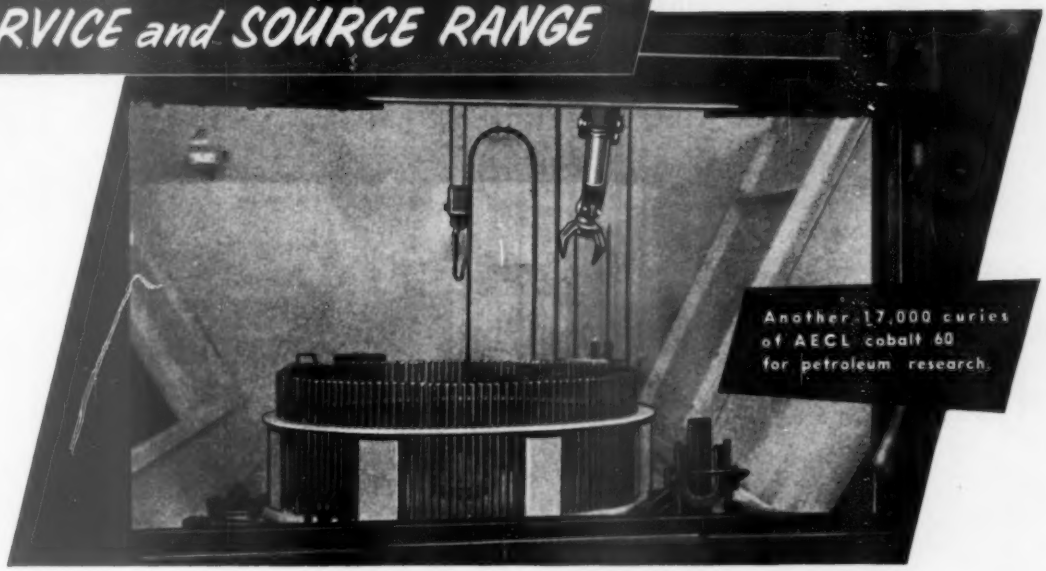
ALCO NUCLEAR CAPABILITY IS READY TO SERVE YOU

For complete information, contact ALCO Products, Inc., Nuclear Components, Dept. 138, Schenectady 5, New York.

Cable address: LOCOMOTIVE, N. Y.

COBALT 60

SERVICE and SOURCE RANGE



A "Weldcaps" Cobalt 60 source supplied by AECL, in the hot cell at SINCLAIR RESEARCH LABORATORIES INC., Harvey, Illinois.

For your Gamma Irradiation requirements choose A.E.C.L. COBALT 60

- **Can be supplied in kilocurie quantities.**
- **Versatile PELLET and SLUG forms enable you to choose any source configuration you desire.**
- **AECL's highly acclaimed "Weldcaps" (stainless steel, welded capsules) are available in a wide range of standard sizes. Special sizes can be made up as required.**

Cobalt 60 is

- Penetrating — (excellent uniformity of dose),
- Reliable — (no complicated electrical equipment to break down at critical times),
- Constant — (calibrate once, then forget about it),
- Simple — (no induced activity in irradiated materials; Monochromatic radiation).

IRRADIATOR DESIGN and FABRICATION SERVICE

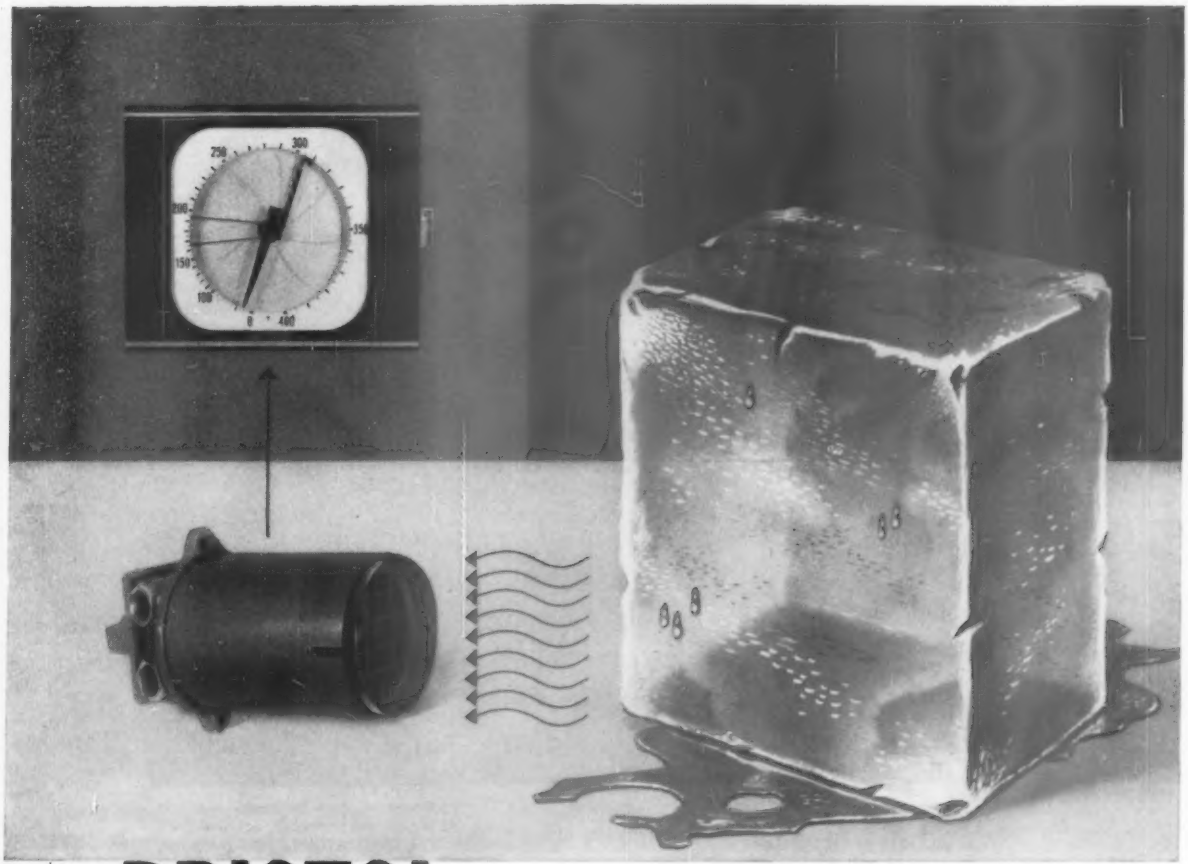
Take advantage of AECL's years of experience and knowhow for assistance regarding any aspect of your research or production irradiator requirements.

For further information, please write to —

ATOMIC ENERGY OF CANADA LIMITED

Commercial Products Division • P.O. Box 93 • Ottawa • Canada

59 2 KC



new BRISTOL low-range radiation pyrometer

IDEAL FOR NO-CONTACT, CONTINUOUS TEMPERATURE MEASUREMENTS ON

Rubber	Plastics
Synthetic rubber	Carpeting
Tile	Mineral aggregates
Roofing shingles	Chemical flows
Adhesives	Petroleum flows
Blackened or unpolished aluminum	Beverage flows
	Reactor kettles
	Mill rolls
Textiles, synthetic and natural fibres	Furnace or oven charges or exteriors
Paper	Foundry molds

...and many other substances; web processes or products; conveyed, rolled or extruded products; and stationary objects.

0-200° F and other ranges to 1100° F · Direct reading charts, scales in F or C · Calibrated interchangeable head units · Automatic built-in ambient compensation · Easy emissivity compensation

Here's the first radiation pyrometer that really gets down to 0° F.

It's the Bristol Velotron Pyrometer System—so sensitive you can sight the radiation unit (at lower left above) on your hand and get an accurate temperature indication.

And on the high end, spans and ranges are available up to 1100° F or corresponding ranges in degrees Centigrade.

Charts and scales are direct reading, in degrees F or C, even on the lowest ranges. No laborious calibration runs, calculations; no curve consulting needed! And you get famous Bristol Dynamaster* Recorder accuracy —proven in thousands of installations.

Ambient temperature compensation is automatic, completely contained in recorder unit (no third unit needed), and allows use in ambients up to 135° F.

A simple knob adjustment allows compensation for emissivity characteristics of target material from black body on down.

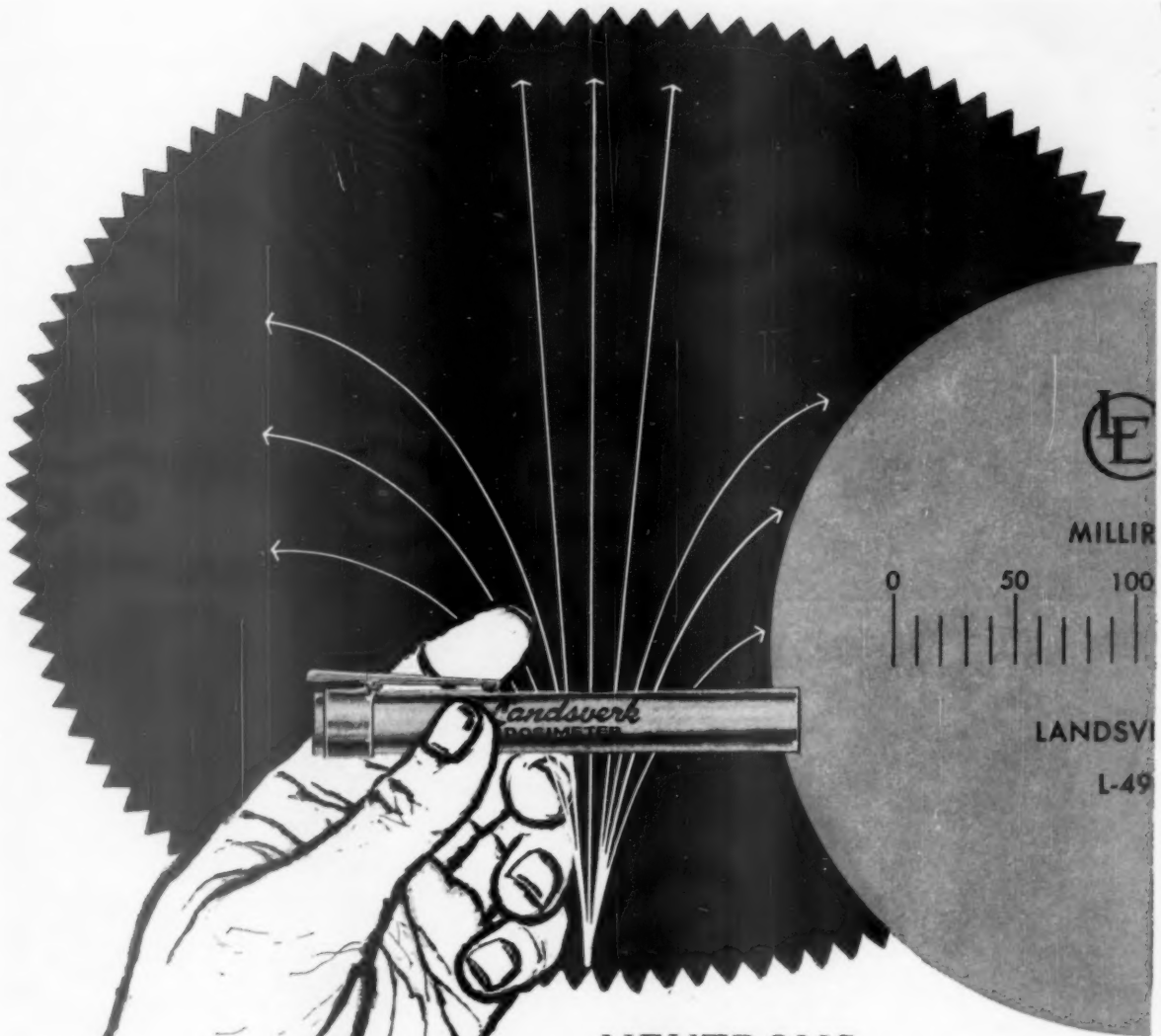
Interconnection cables are standard copper wire; no special, preselected lengths required.

Write for complete technical data on this outstanding new Bristol contribution to industrial pyrometry. The Bristol Company, 147 Bristol Road, Waterbury, Conn. ⊙ 31

*T. M. Reg. U. S. Pat. Off.

BRISTOL...for improved production through measurement and control

AUTOMATIC CONTROLLING, RECORDING AND TELEMETERING INSTRUMENTS



NEUTRONS

GAMMA RAYS

X-RAYS

are accurately measured by the

Landsverk Model L-49 200 MREM

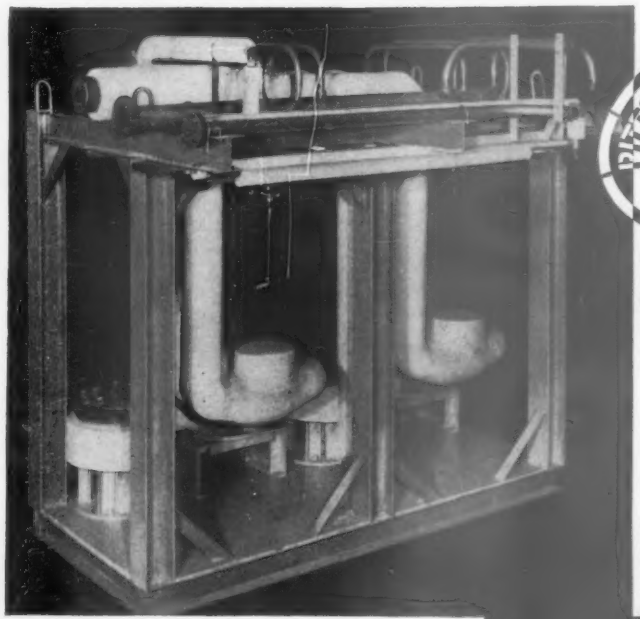
Thermal Neutron Dosimeter

Write Dept. C for free catalog.

Landsverk Electrometer Company

641 SONORA AVE., GLENDALE 1, CALIFORNIA

FIRST NAME IN DOSIMETERS FOR MORE THAN A DECADE

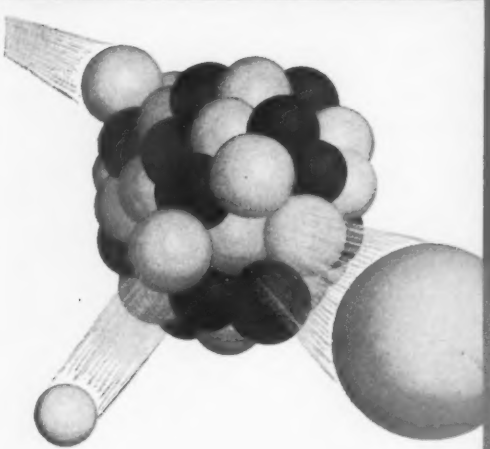


PITTSBURGH PIPING NUCLEONICS JOB NU-4017

One of a battery of stainless steel test loops fabricated at Pittsburgh Piping. Shown insulated; ready for shipment.

Stainless steel de-mineralizers—larger unit is 14" in diameter; its wall thickness is 1½".

PITTSBURGH PIPING NUCLEONICS JOB NU-1621



PP-39

Fabricated by Pittsburgh Piping for Nucleonics

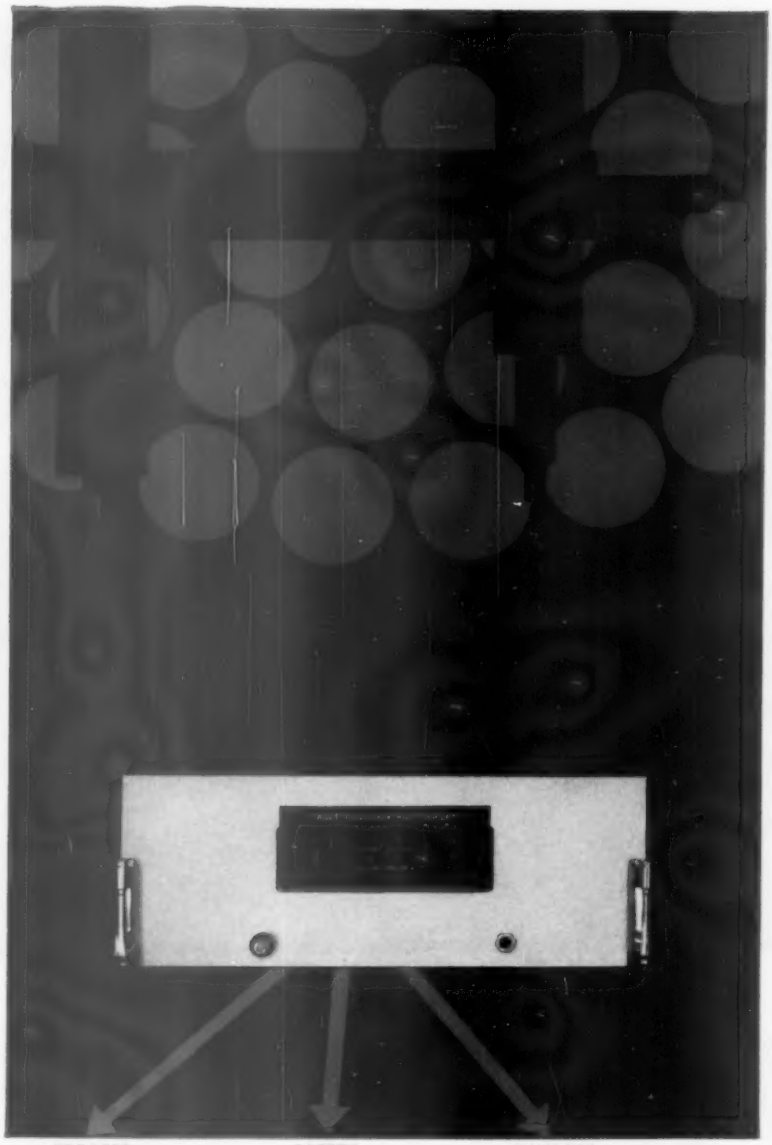
The stainless steel test loop and the de-mineralizers shown above are typical of the nucleonic piping work that goes through Pittsburgh Piping shops.

This type of fabrication is a "natural" for us. We pioneered the application of austenitic steel piping materials for central stations operating at 1050°F and above, and fabricated piping for America's first atomic-powered submarine and central station. Today we are producing a wide variety of piping components for leading builders of nuclear energy installations. We invite you to inspect our plant, meet our people, and use our facilities on your nucleonic jobs.

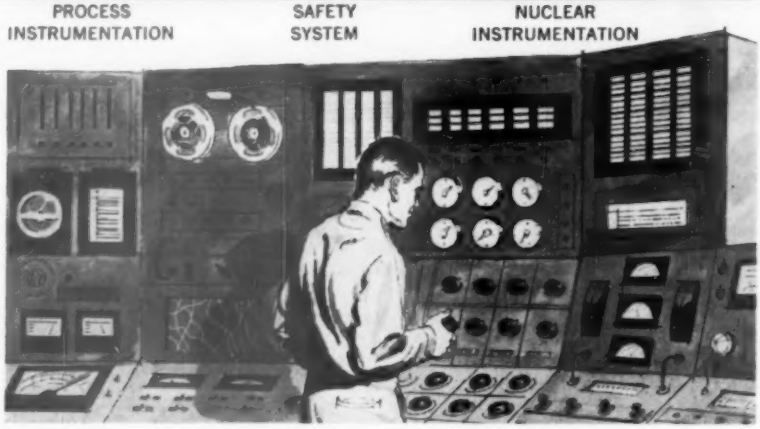
PIONEER FABRICATOR OF HIGH PRESSURE PIPING FOR NUCLEONICS

Pittsburgh Piping AND EQUIPMENT COMPANY
158 49th STREET · PITTSBURGH 1, PA.

Atlanta . . . . Whitehead Building
Chicago . . Peoples Gas Building
Cleveland . . . Public Square Building
New Orleans . . . . . P. O. Box 74
New York . . Woolworth Building



PROCESS INSTRUMENTATION | SAFETY SYSTEM | NUCLEAR INSTRUMENTATION



A TALENT FOR MODULAR NUCLEAR CONTROL SYSTEMS

Fault-isolation circuitry reduces reactor down time from hours to minutes

Hours or even days of reactor down time to search for a control system malfunction can be reduced to minutes—with self-checking and fault-isolation circuitry built into Stromberg-Carlson transistorized nuclear control systems—checks reactor process instrumentation as well as nuclear channels.

Highly skilled, specially trained technicians are not required for normal operation. Trouble is pinpointed in seconds, and plug-in, interchangeable modules can then be replaced within minutes.

Fail-safe operation achieved in Stromberg-Carlson nuclear control systems through proper use of reliable and safe solid-state circuits.

Transistorized systems available for marine power plants, portable power installations, and commercial central power stations.

Specifications upon request.

Applications engineers, engineers and scientists with reactor instrument experience interested in joining this expanding program may contact our Manager of Technical Personnel.

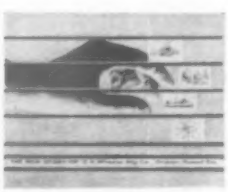
See us at the 6th Annual Nuclear Congress at the Essex House in New York City.

STROMBERG-CARLSON
A DIVISION OF **GENERAL DYNAMICS**
1496 NORTH GOODMAN STREET • ROCHESTER 3, N. Y.

NEW! ...the combination of

the combination of these two equipment in designing or procuring components for

Write today for this brochure:
The New Story of
C. H. Wheeler Mfg. Co. / Griscom-Russell Co.
c/o C. H. Wheeler Mfg. Co.
19th St. and Lehigh Ave.
Philadelphia 32, Pa.



among the many components offered are: Condensers, Ejectors, Heat Exchangers — Bare Tube, Extended Surface Heat Exchangers,

C. H. Wheeler Mfg. Co. / Griscom-Russell Co.

lines offers important savings for management and engineering staffs engaged a variety of applications in power plants, marine, process and nuclear systems.

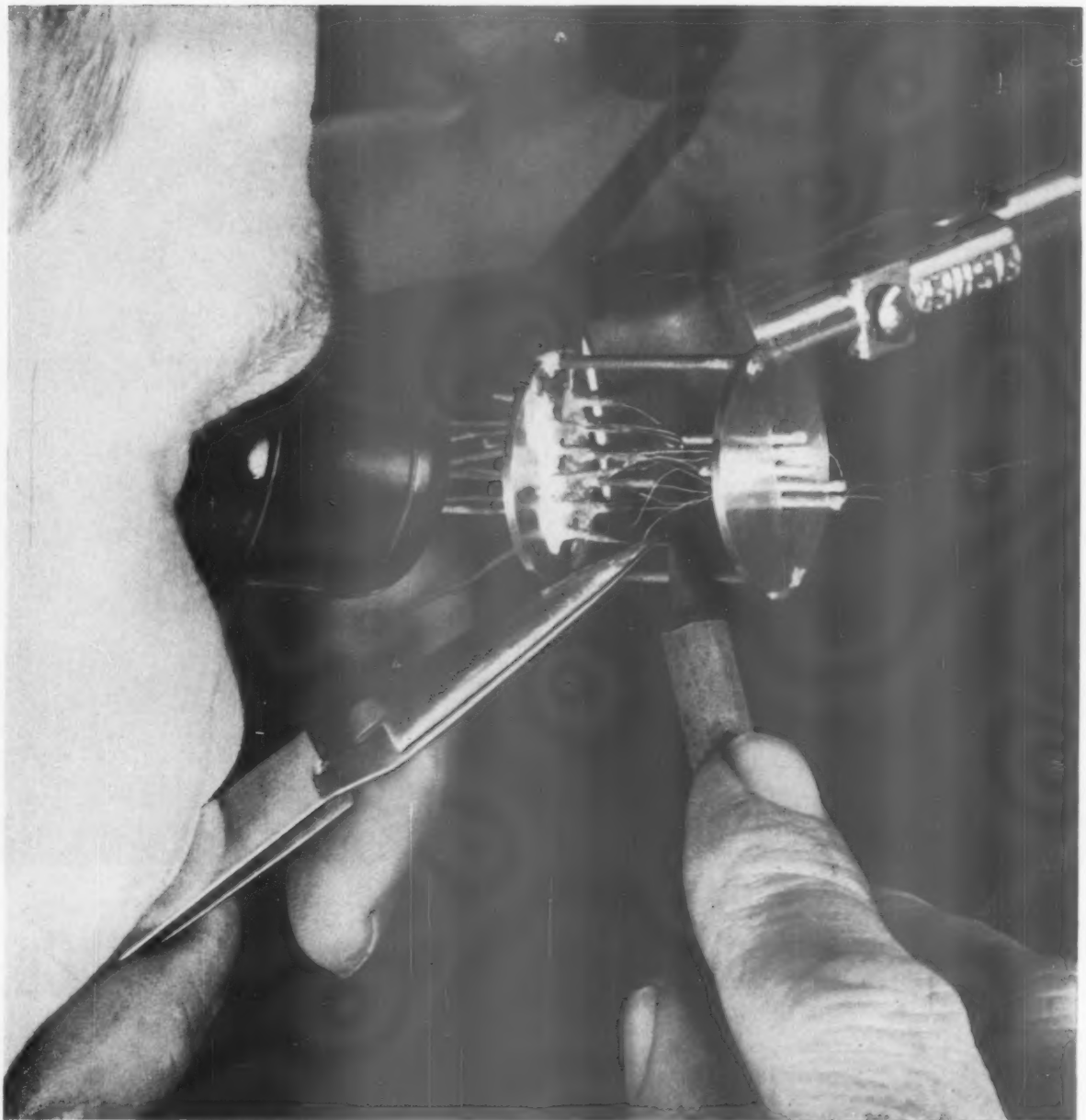
C. H. Wheeler Manufacturing Company, with 71 years' experience manufacturing condensers, ejectors, pumps and other components for the power, marine, process and nuclear industries, and Griscom-Russell, with 92 years' experience in the heat exchange field, are uniting to create an important pool of experience, products and services unmatched in industry today. The advantages offered by this combination are improved and increased selection, distribution and service, resulting in substantial savings for the current and potential customers of both companies.

C. H. Wheeler Mfg. Co./Griscom-Russell Co.

PHILADELPHIA, PENNSYLVANIA MASSILLON, OHIO

SUBSIDIARIES OF HAMILTON-THOMAS, INC.

Evaporators, Marine Distilling Plants, Marine Systems, Pumps, Nuclear Components, Valve Actuators, Custom Fabrication and Machining



Making thermocouple connections on an in-pile test capsule

Reactor design and development begins with the mathematician and the physicist. But concept must yield to blueprint, blueprint to sure, dependable hardware. No less than the mathematician, the instrument maker, the welder, the machinist, the electronics technician—in fact, a complete spectrum of skills makes up the reactor team. NDA has these skills in full measure in its White Plains and Pawling centers for reactor design and development.

Let this team work on *your* nuclear reactor problems.

Opportunities exist at NDA for qualified scientists and engineers.

THIS, TOO, IS REACTOR DEVELOPMENT

a complete reactor company

NDA — **NUCLEAR DEVELOPMENT CORPORATION OF AMERICA**

WHITE PLAINS, N. Y. TEL. WH. 8-5800

NDA EUROPE 31, Rue du Marais, Brussels, Belgium

NUCLEONICS NEWS OF THE MONTH

Shippingport: Will Get 150-Mwe Core, No New Generator

AEC has abandoned, for economic reasons, the much-negotiated plan to take this country's prize power reactor—the pressurized-water reactor at Shippingport—to a 150-Mw electrical generating station. Instead, PWR will feed power to the 100-Mwe generator now at the site and dump everything over that to a heat sink when a second core of 150-Mwe equivalent (525 Mwth) is installed some time in the next three years.

The Commission's decision, announced by Chairman John A. McCone at Congressional hearings last month on AEC's construction program for fiscal '61 (*see page 30*), came after a special six-man committee unanimously recommended against installation of additional generating equipment. The group, headed by AEC Assistant General Manager Alfonso Tammaro and American Electric Power President Philip Sporn, advised the Commission:

"The Committee is not unmindful that if steam energy created by PWR-2 [PWR with its second core] is . . . dissipated to the atmosphere by the heat sink, the operation would have the appearance of a wasteful use of a natural resource, i.e., atomic fuel. We must emphasize, however, that it cannot in fact be regarded as wasteful to dissipate energy in this way when no economical means exist to use it and where the production of the steam is the necessary result of a desirable research and development project.

"Shippingport has already served its purpose as a demonstration nuclear electric power plant; insofar as any further purpose might be served by Shippingport operating as a demonstration plant generating electric power at a rating of 150 Mwe this purpose will have been performed by the time Shippingport generation could come into being by at least two other plants which could be considered as the sons or daughters of Shippingport and which will be operating at that time at or above 150-Mwe rating [Indian Point and Yankee]."

Duquesne Light Co. and AEC had been negotiating for months on extra generating equipment but Duquesne was insisting that its funds (just over $20-million for generator and transmission equipment) would have to buy steam at the going conventional rate (2–3 mills). AEC could have put up the $20-million itself (compared with $4-million for the heat sink) but this entailed many complications, not the least of which were budget pressures and disposal of the electricity. It was primarily for economic reasons, however, that a decision was made to settle for a heat sink, according to McCone:

"Both these possibilities [generator and heat sink] were thoroughly investigated by the Duquesne Light Co. and the Commission and it is jointly concluded that expanded electrical generation is not economically feasible under the circumstances. Use of a heat sink for power dissipation meets all the requirements for proving out the higher power capabilities and thus the development objectives of PWR Core-2."

SHIPPINGPORT'S FUTURE

The Tammaro-Sporn Committee, which held its first meeting Jan. 22 and its sixth and last Feb. 6, included W. S. Peterson, Los Angeles Dept. of Water and Power; Henry D. Smyth and Eugene Wigner, Princeton Univ.; and Robert E. Wilson, designate member of AEC. The Committee's paper, taken together with a fact-finding study conducted in December and early January by an AEC staff group, presents a comprehensive report on what has been done at Shippingport since it went critical in December, 1957, and what is scheduled to be done over the next 5–8 years.

The Schedule

The first PWR seed was pulled out of the core last fall and Seed-2 will begin operation this month; it will be depleted in September, 1961. If the blanket is able to take a third seed it will be installed in December, 1961, and pulled out in January, 1963. Core-2 would then go in in March 1963 for operation in August. If Blanket-1 cannot take a third seed, Core-2 will be installed in November next year and begin operation in April, 1962.

The Tammaro-Sporn group urged an attempt to raise PWR to more than 60-Mwe with Seeds 2 and/or 3; it also urged the introduction of plutonium into Seed 3 if there is one.

The group emphasized its unanimous finding that Core-2, which has

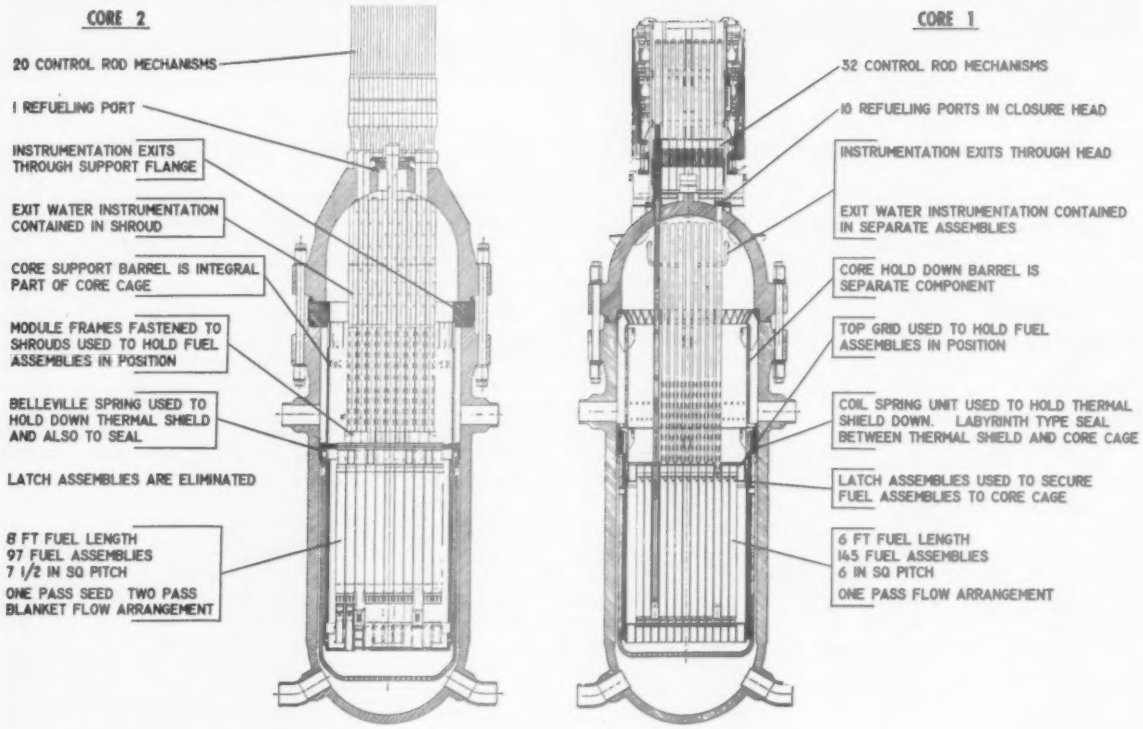
Robert Wilson confirmed as 5th AEC member

Robert E. Wilson, 67, industrial scientist, chemical engineer, inventor, retired board chairman (1945–58) of Standard Oil of Indiana, and a member of AEC's General Advisory Committee since 1956, was named to Harold Vance's unexpired term as a member of AEC—plus the full succeeding five-year term ending June 30, 1965. He was promptly approved by the Senate section of the Joint Committee on Atomic Energy, and—two days later—by the full Senate. Wilson told JCAE "there's been a little too much optimism on nuclear power; we may miss the 1968 goal by a year or two."

Rover gets $11-million restored; Orion to Air Force

AEC restored $11-million, cut by the Budget Bureau, to the Rover nuclear-rocket project (bringing it to $50-million for fiscal 1961); AEC had sought a total of $55-million. The Air Force took back the Orion project (space propulsion by controlled nuclear explosions) from Defense Dept.'s Advanced Research Projects Agency, after NASA declined to pick up General Atomic's $90,000/mo tab for continuing the Orion effort.

PWR-2: Larger, Simpler, More Powerful


CORE 2
20 CONTROL ROD MECHANISMS
1 REFUELING PORT
INSTRUMENTATION EXITS THROUGH SUPPORT FLANGE
EXIT WATER INSTRUMENTATION CONTAINED IN SHROUD
CORE SUPPORT BARREL IS INTEGRAL PART OF CORE CAGE
MODULE FRAMES FASTENED TO SHROUDS USED TO HOLD FUEL ASSEMBLIES IN POSITION
BELLEVILLE SPRING USED TO HOLD DOWN THERMAL SHIELD AND ALSO TO SEAL
LATCH ASSEMBLIES ARE ELIMINATED
8 FT FUEL LENGTH
97 FUEL ASSEMBLIES
7 1/2 IN SQ PITCH
ONE PASS SEED TWO PASS BLANKET FLOW ARRANGEMENT
CORE 1
32 CONTROL ROD MECHANISMS
10 REFUELING PORTS IN CLOSURE HEAD
INSTRUMENTATION EXITS THROUGH HEAD
EXIT WATER INSTRUMENTATION CONTAINED IN SEPARATE ASSEMBLIES
CORE HOLD DOWN BARREL IS SEPARATE COMPONENT
TOP GRID USED TO HOLD FUEL ASSEMBLIES IN POSITION
COIL SPRING UNIT USED TO HOLD THERMAL SHIELD DOWN. LABYRINTH TYPE SEAL BETWEEN THERMAL SHIELD AND CORE CAGE
LATCH ASSEMBLIES USED TO SECURE FUEL ASSEMBLIES TO CORE CAGE
6 FT FUEL LENGTH
145 FUEL ASSEMBLIES
6 IN SQ PITCH
ONE PASS FLOW ARRANGEMENT

been under design for a year, could well have been the same size as Core-1 (6 ft) with a rated output of only 100 Mwe, instead of 150 Mwe. The smaller core would have been less expensive with little loss of technical advantage, the Committee said.

"We have been assured that planning and developmental work on Core-2 with a rating of 150 Mwe has already proceeded so far as to render moot the question of undertaking Core-2 with a somewhat lower rating," the Committee declared. "We feel bound to say, however, that the review that the Committee was able to make did not convince [it] that the increased costs were warranted by the technical advantages of a rating above the 100 Mwe for which generating equipment is already installed."

The Committee's preference for a 6-ft, rather than an 8-ft, core brought it under sharp attack by Admiral Hyman Rickover, Shippingport supervisor, at a JCAE hearing March 10:

"You know how I feel about committees. . . . I don't see how you can have people who are not immersed in the program sit down in a short period of time and arbitrarily say such things. . . . I will make the categorical statement that running the reactor over 100 Mwe is beneficial. And the surest way to have a successful program is to let a man who believes in it work his head off."

The Program

"The distinguishing characteristic of PWR," the Tammaro-Sporn Committee pointed out, "is the fact that it is the only seed-and-blanket concept that has been implemented in the U. S. civilian water-reactor program so far. It would appear highly desirable that this be fully developed and that Core-1 blanket life should be extended as far as possible." This language pointedly describes the major technical goal of PWR in the years ahead: a very high performance seed-and-blanket-type core with, ultimately, three times the energy output of Core-1 and twice the power density of Core-1. The major differences between Cores 1 and 2 show the steps toward this goal:

1. Core-2 power will be 525 Mwth with four coolant loops; Core-1 is 231 Mwth with three loops.

2. Core-2 will have plate-type uranium-oxide fuel elements clad in Zircaloy-4 in both seed and blanket, compared with metallic plate elements in the seed and rod-type UO_2 elements in the blanket of Core-1.

3. Core-2 will have a different geometry and will require only 20 controls rods, compared with 32 for Core-1.

4. Core-2 is designed for 20,000 equivalent full-power hours in the blanket and 10,000 for the first seed (8,000 and 3,000 for Core-1).

Other features of Core-2: a 2-pass coolant flow in the blanket; a 2-ft longer core (8 ft); a single refueling port in the head (now 10 ports); a flange to take instrument leads between the pressure vessel and head (now through the head); power density of 130 Kw/liter for the seed and 40 Kw/liter for the blanket (now 75 and 25, respectively); and use of burnable poisons to reduce the peak-to-average power distribution, increase seed life and reduce the amount of mechanical control.

The Cost

Through Oct. 31, when it went down for seed replacement, PWR had generated 388.5-million kwh of electricity at an estimated cost (based on utility practice) of 43.44 mills/kwh—25 mills for fixed charges and 18.44 mills for fuel-cycle cost. A total of $163-million had been spent on the plant: $75-million for construction, including first seed and blanket; $81-million for research-development; $4-million for fuel fabrication (seed-2, spare subassemblies and start of

PWR Waste Stirs Furore

An AEC-U. S. Public Health Service mission to Wheeling, W. Va., on March 18 successfully quieted a "furore" over low-level wastes dumped into the Ohio River by Shippingport. A spokesman for the local critics, M. H. Berry of the West Virginia Academy of Sciences, said after an all-day meeting that the government had "pretty well convinced everybody present that there wasn't anything to worry about." Newspapers on both sides of the Ohio had been headlining charges that Shippingport's discharge was harmful.

Core-2); and $3-million for test operations.

The modifications for Core-2, including heat sink, are budgeted at $9-million. Operating expenditures, including fabrication of Seed-3 and Core-2, are estimated as follows: fiscal '60, $18.5-million; '61, $19-million; '62, $12.3-million; and '63–'65, an average of $7.5–$9-million.

The 43.4-mill cost of electricity through Seed-1 is expected to drop to 39.3 mills for Seed-2 (14.3 for fuel), to 20 mills for Core-2 (7 for fuel), and to 17.6 mills (4.6 fuel) for repeat cores. The Tammaro-Sporn core comparison:

	PWR-1	PWR-2
Power	68 Mwe	150 Mwe
Life (1 blanket, 2 seeds)	12,500 hr	20,000 hr
Energy, kwh	850 million (end-'61)	3 billion
Power density		
Seed (liter)	75 kw	130 kw
Blanket	25 kw	40 kw
Wt of enriched U-235 (seed)	75 kg	290 kg
Fabrication cost, 1 blanket, 2 seeds ($10⁶)	16.1	17.0
Cost, natural-U and U-235 ($10⁶)	3.1	10.0
Fuel cost, mills	19/kwh	6.6/kwh

The Tammaro-Sporn Committee's last recommendation was not likely to warm Adm. Rickover's heart any more than did the comments on an 8-ft core: it came pretty close to a suggestion to take the project out from under Rickover as chief of the Naval Reactors Branch of AEC's Reactor Development div.

"The Committee has . . . observed differences of approach and philosophy between the Shippingport project and the rest of the AEC reactor program. We believe that the Shippingport project and the entire civilian power program would be more effective if all were coordinated under the National Civilian 10-Year Power Program as fixed by AEC policy."

Expanding Role Seen for Both National Labs, Industry

Comfort for both sides in the recent debate over the role of the national labs can be found in the long-awaited report by AEC to the Joint Committee on Atomic Energy, published last month. The massive (2 vols., 384 pp) study, titled "The Future Role of the AEC Laboratories," sees expansion for both groups in federally-financed research in 1960–70:

"Despite leveling off or decreases in some programs . . . present indications are that the volume of research-development work incident to discharge of the Commission's statutory responsibility will increase during the next ten years . . . To carry out these program changes and to remedy existing deficiencies, research and development facilities estimated to cost $700-million are under construction or authorized."

The report has warm words for the job being done by the 20 labs discussed (41,500 employees, $600-million worth of research work in fiscal '60 using $947-million worth of facilities). "AEC's labs today are vital national assets . . . constituting the major source of new fundamental facts about atomic energy . . . AEC believes that the laboratories must continue to be supported vigorously . . . "

But those who have recently complained about the labs doing work that could be done by private industry will also find such passages as:

"The discussion of the roles of the AEC labs [herein] does not assume that the labs will be assigned exclusive areas of work for which they alone will receive government support . . . The discussion does envisage an orderly progression to industry of development projects [done] by AEC labs.

"The Commission intends to encourage this progression and to support, through appropriate contracts with industry, such further development as warrants continued government support . . . In the performance of their work, AEC labs should utilize to the maximum extent practicable the services which industry can provide . . .

"AEC intends that the labs will remain paramount in pioneering work as the inventors and developers of new concepts and as the talented source of varied capabilities for tackling complex and unusual assignments. But increased responsibility will continue to be placed on industrial organizations to perform AEC-supported development, as the nuclear field progresses . . .

"In the fields of engineering and process improvement, simplification and cost cutting, and design for ease of maintenance and reliability of operation, where much remains to be done in order to achieve the goal of competitive power, industry, with both federal and private financing, will play the major role, complementing the advanced work of the laboratories . . .

"It is the intent of AEC to assure that those labs essential to weapons research and development [Los Alamos, Lawrence Radiation Lab at Livermore, and Sandia] be maintained as strong and vigorous institutions. Should there be some decrease in weapons research and development needs, consideration will be given to expanding these labs' non-weapon functions as the national interest requires . . . "

Where the Labs are Going in the Sixties

Most of the report is given over to detailed consideration of the work of each of 20 labs. For each one the report tells what it has done, what it is doing, what it wants to do in the next ten years, and, separately, what AEC plans for it to do. A digest of AEC forecasts for some of the labs:

Argonne—Moderate expansion of the staff (now 3,600) contemplated, and significant changes in program emphasis. Completion of the Zero Gradient Synchrotron will place Argonne in position to carry on "one of the nation's major programs" in high-energy physics. The chemistry program will turn more to work on transplutonium elements; the metallurgy program will shift more and more to plutonium. The relative size of the reactor program will decline; boiling water work will be phased out, fast breeder work will continue, and advanced concepts will get closer study.

Brookhaven—A substantial expansion of effort is anticipated, especially in the decade's first five years. Nearly half the growth (present staff, 1,800) is expected in the high-energy physics program with completion of the 30-Bev synchrotron and improvement of the Cosmotron.

Oak Ridge—The staff (now 5,000) will remain stable in the next decade. Reactor emphasis will be on gas-cooled reactors and thermal breeders.

Los Alamos—Slow, limited growth foreseen (present staff 4,070). Nuclear rocket propulsion is shifting in emphasis from feasibility demonstrations to technical support and advanced concepts.

U. S.-Euratom Relations Strained; Rapprochement Foreseen

Two years ago this summer, the U. S. and the six Western European nations making up the European Atomic Energy Community (Euratom) embarked on an exciting economic and political program to help European utilities install 1,000,000 kwe of nuclear power capacity by 1965. The goal was to have been met by spending some $350-million for reactors (most of it utility money) and $100-million for research and development.

Last month, this bold effort had not only collapsed but the arm-in-arm, hands-across-the-Atlantic cooperation which had nurtured it was in an advanced state of deterioration. The failure of the phase-1 effort to get at least four projects going for completion by Dec. 31, 1963 had long been foreseen (NU, Dec. '59, 28; Sept. '59, 25; and May '59, 28). What had not been foreseen was the break in U. S.–Euratom relations which has followed this country's decision to write-off the first phase (with only the SENN proposal in) and to restrict the joint research effort to a few million dollars until projects additional to SENN are put forward.

Euratom Chief Etienne Hirsch, in a bitter letter reacting to the new U. S. policy on the joint program, accused the U. S. of unilaterally turning a bold program into little more than a shell of one. He was incensed over the U. S.' unwillingness to merge phase-1 into phase-2—to keep the 1,000,000-kwe power goal alive through 1965—and disappointed in what he considers a lost opportunity to keep a strong cooperative effort going through the research-and-development program.

Contact Re-established

In a move to restore the heretofore excellent relations between the U. S. and Euratom, Etienne Hisch and AEC Commissioner John Floberg re-established contact last month by transatlantic phone. The agreement they worked out does little to change the U. S. position described on this page by U. S. Ambassador W. W. Butterworth, but it does open the way for a more aggressive effort by Euratom. The two will move to amend the joint arrangement, it was agreed to: 1. permit Euratom to proceed with its $50-million commitment under the $100-million joint research-and-development program (some of these funds would probably be spent on proposals sponsored jointly by U. S. and European firms); 2. increase the supply of U. S. enriched uranium and plutonium available to Euratom; and 3. permit leasing, rather than sale, of reactor fuel (as suggested in the Wadsworth letter).

BUTTERWORTH TO HIRSCH TO BUTTERWORTH

Hirsch was notified of the new U. S. position about Feb. 1 by letter from W. W. Butterworth, U. S. ambassador to the European Community. The Hirsch reply came back quickly, accompanied by a request to transmit a copy of it to the Joint Committee on Atomic Energy. Excerpts from the exchange tell the story of a faded dream:

BUTTERWORTH: "AEC and the Dept. of State support the continuation of the joint reactor program within the original framework and to the extent presently authorized. This decision results from the estimate that such a program is the maximum which can be supported at the present. Within this framework, the specific elements foreseen, which may well be affected by Congressional reaction, would be as follows:

"1. The SENN proposal would be accepted as a satisfactory project. . . . While the AEC would propose submitting the present SENN package to the Joint Congressional Atomic Energy Committee as it now stands, the AEC would not request authorization of appropriate fuel guarantees until these arrangements become definitive. With the acceptance of the SENN proposal, Washington would consider the 1963 phase of the joint U. S.–Euratom program as terminated. . . .

"2. Approval would be given for the issuance of invitations for the two reactor projects currently authorized for 1965 under the joint program [this summer is the proposed schedule for such an invitation]. There would be no increase or liberalization of the benefits offered by the U. S.

"3. The joint research-and-development program would be continued but would be limited to a modest amount in connection with the SENN project, in addition to the approximately $1.7-million already authorized by the Joint Research Board [for each side of the Atlantic]. This limitation of research-and-development proposals to the SENN project would apply until responsive proposals to build reactors have been received in connection with the invitations for the 1965 phase of the joint program.

"4. While the SENN project would be carried forward on the existing basis of deferred payment for fuel, the AEC is willing to consider changing the terms of the present agreement to provide for lease of materials on terms and conditions consistent with U. S. domestic leases. If such a change is made, it would be applicable to the SENN project, if desired. . . . "

HIRSCH: "The views expressed in your letter may have unfavorable consequences for this cooperation, of which the political aspects have always been considered as of even greater significance than its technical and economical elements. The Euratom commission still hold this view. At this very moment the most serious consideration is being given to the pooling of resources of the free world, to meet the challenge of other forms of society.

"It would be most regrettable if the execution of an international agreement between the U. S. and our European Community, providing for a joint farsighted and enlightened effort in a field where U. S. S. R. technology is catching up with western achievements, were at this moment to be jeopardized by the difficulties which are being experienced at its very beginning.

"We still are and remain convinced of the compelling necessity of broad and resourceful nuclear research-and-development programs, of the inevitable need of atomic energy for peaceful purposes in the foreseeable future and of the feasibility to approach 'the competitive range of conventional energy costs in Europe' even at an earlier date.

"We feel therefore very strongly that unhampered continuation of the joint research-and-development program as a forceful means of vitalizing the related joint reactor program is much more indicated than restriction of the latter to such limitations as to preclude the realization of serious and seriously considered possibilities in the field of power plants and, as a consequence of that, to see the former [Research and Development] program limited to a modest amount.

"Your proposal to consider the 1963 phase as terminated and to pass on immediately to the 1965 phase would in our opinion have very negative results in

Europe. This would preclude any further useful action by the commission, within the framework of our agreement, in connection with the Dutch and Berlin projects or other potential participants.

"The closing of the 1963 invitation and the issuance of the 1965 invitation would certainly not serve as an incentive for speeding up projects now well underway. We therefore think it advisable to revert to our proposal of merging the two phases into one single 1965 program."

U. S.–EURATOM RAPPROCHEMENT

U. S. officials accepted the Hirsch reaction as something to be expected from the man who is almost personally responsible for the success of the Euratom experiment. They felt they had no other course of action open to them once phase 1 had collapsed. To go along with Hirsch on either of his alternatives—merger of the two phases and maintenance of a major research program—entailed a request to Congress for amendment of the Euratom Cooperation Act. This, it was felt, would have brought on a fight with JCAE which the Administration had little chance of winning.

U. S. officials were predicting that the breach would heal quickly and that negotiations would proceed on: 1. getting an invitation out this summer for the two '65 reactors; and 2. developing an over-all U. S.–Euratom bilateral agreement similar to those now extant with Euratom's member countries but broader. It was also pointed out that AEC could ask Congress to expand the '65 phase to more than two reactors, if appropriate.

Majority of Industry Leaders Still Can See an Export Market

The American power reactor industry thinks it will continue to have an export market, although at a very low level. Disappointed in the record of atomic efforts abroad in the past five years, it nevertheless does not feel we should write off export possibilities, and has in fact a number of prescriptions to offer the government on what it could do to improve the dark export picture.

And although it disagrees with Euratom President Hirsch's prediction of three months ago that Euratom will meet its 1965 goal of 1,000 Mwe installed capacity despite a painfully bad start, it agrees with him that the long-term demand for additional power is still there.

These are the salient results of a NUCLEONICS survey of the top leaders of the industry. Fourteen men at the "vice-president, nuclear power" level were polled and twelve responded—eight equipment manufacturers, one fuel fabricator, three architect-engineers. Considering that the survey was made in the days immediately following on the collapse of AKS' plans (to build a 150-Mwe nuclear plant in Germany under the U. S.-Euratom program), the results are quite optimistic. They indicate that the hard-headed business leaders of the industry, while expecting no pot-of-gold from exports, are still in the main hopeful for the long haul. Here is a digest of the questions and their answers:

Is the record of American atomic efforts abroad about what you had expected, or is it a disappointment? Why? What had you hoped for?

Eight expressed varying degrees of disappointment, four found what they had expected. (One of the eight called the record "a disappointment although about what was expected"—but then added, "we had high hopes it might have turned out better.")

One comment called it "a reasonable accomplishment" although not as great as hoped for; another called the program "over-sold, over-rushed, over-complicated; the overseas customers wanted too much; U. S. government groups, international groups and foreign customers never really decided what their objectives were; the U. S. was paternalistic and dominating; foreign and international groups were grasping and highly nationalistic; U. S. industry cut each other's throats."

Wrote another, "the U. S. government and U. S. industries did their utmost to develop the potential market"; another felt that "more positive government action on such things as fuel guarantees, R & D support, indemnity and patent problems could have materially increased the scope of U. S. industry's foreign activities."

If you foresee an improvement in our market prospects,

Industry Leaders Tell the Government

One of the more interesting results of NUCLEONICS' *survey of industry leaders was the comments it elicited on what the government—and industry as a whole—should have done, and could be doing, on behalf of a more favorable export market. The question, and a summary of the answers:*

Do you think U. S. government or industry can do anything to remove impediments to our export business? If so, what?

Nine said yes to the first question; only three felt the government had done all it could do, or that the problems were purely economic and beyond the influence of governmental action. As for action by industry, one wrote, "industry has done about everything except *give* it away."

Three points clearly dominated the list of things industry wants the government to do: provide patent protection for U. S. industry, solve the international third-party liability problem, and—above all—reduce controls and red-tape generally, and in particular simplify the complicated arrangements under which U. S. fuel is made available to foreign users.

Among other points mentioned for governmental action were: more attractive financing; development of standards and licensing procedures; longer contract times and agreement on longer-range programs—not just year-to-year operation. It was suggested the government could require some part of U. S. financial aid to be spent for U. S. equipment or services, and that the government "can be more positive about prices and arrangements" for U. S. materials and services. Another injunction to Washington: "stop giving away what industry is trying to sell."

Advice for industry itself included these points:

- "Produce concrete results—mostly technical, and less opinion disguised as study reports."
- "Industry as a whole could do quite a bit to place the reactor business on a realistic and acceptable basis abroad by working together to present the facts."

to what factors do you look for this improvement?

These suggested factors were ticked by the number shown:

Lowering of power cost of nuclear power	9
Lowering of capital cost of nuclear power	7
Increase in cost of fossil-fuel power	6
Increase in demand for power from any fuel	4
Improvement in competitive attractiveness of U. S. reactors	4
Lack of domestic fossil fuels, or of foreign exchange to import it	1
Achievement of enough research-development work to increase confidence in reliability of nuclear power	1

In addition, these other factors were written in:

Desire to look ahead and be prepared

Demonstration of domestic use in normal business manner, with government subsidies—if any—established on a believable long-term basis

What kind of help do you think the foreign countries that are potential customers for new nuclear power equipment expect of the U. S. in the nuclear field?

Technology was the answer most frequently cited—the U. S. should maintain leadership in technology, and should make its know-how available. One replier specified "access to operating experience on U. S. reactor power stations."

Next came financial aid, with some specifying aid on research-development work, aid as back-up for fuel guarantees, aid as protection against excessive operating losses. (One respondent summed up the two leading replies: "Dollars—more dollars—dollars! Information—know-how—grey matter!")

Third came fuel and assurance on continued availability of enriched fuel. Other points were: aid in solving third-party liability and insurance problems; simpler regulations on trading; development of safety codes and regulations; and "to know what U. S. materials and services will be available and their cost."

Observed one reply: "They [potential foreign customers] appear in many cases to expect the U. S. or its industries to accept the technical and financial risks without at the same time having a direct part in the engineering, manufacturing, construction or operation or the resulting financial incentives to take such responsibility."

Asked another: "Why help? If the product is worthwhile, let them pay for it. If not, we are all better off if we keep it at home."

Do you think U. S. governmental aid to foreign nuclear program should be for power reactor construction? just research-development? or both?

Four replied "both"; two said neither. Three believe in just research-development aid, one said reactors, one said fuel, and one wrote in "no answer."

What, in your opinion, are the chief reasons why the U. S.–Euratom power reactor program has fallen short, until now at least, of its goals?

The suggested reasons scored thus:

Greater-than-anticipated short-term stocks of fossil fuels	10
Presently uneconomic nature of nuclear power	9
Greater-than-anticipated long-term reserves of fossil fuels	5
Lack of clear solution to third-party liability problem	4
Disinclination to tie power program to U. S. enriched-U supply	3
Lack of sufficient funds by Euratom utilities	2
Obstacles by foreign government in country concerned	1
Insufficient time given by U. S. to prepare proposals	0

The zero scored by the last factor is interesting because this was one of the major complaints of European manufacturers planning to bid in the Euratom program.

Other suggested reasons were:

Desire of customers to wait and see how well plants now being built turn out

Slowness of U. S. to provide positive financial support in most useful form

Euratom seems largely a political end, and why should nuclear power have a unique contribution to offer?

"Never was a well-conceived plan"

"The 'goals' were ridiculous to begin with"

Inertia

Do you think we should write off altogether the export market for power reactors and components? or do you foresee an improvement in the next five years? Do you think there will be a continuing market for U. S. nuclear products after five years?

Seven expect some improvement, four foresee none at all. Five who saw only slight or no improvement in prospects in the next five years nevertheless spoke out against writing off the export market. Eight feel there will be a continuing market after five years for U. S. nuclear products, two do not, one sees demand "for know-how only" and one was doubtful.

"We are just now entering the period of real opportunity abroad for nuclear power systems capable of providing the operating conditions required for truly economic power," one commented, adding, "We foresee a continuing market overseas for [such] systems. Looking ahead five years, this should be the time when we will see the start of installation abroad of advanced plants of real economic promise."

Said another, "No major improvement in U. S. power reactor sales abroad can be expected in the immediate future. However, the export market should not be written off altogether. The proper form of government support and coordination with U. S. industry, together with attractive technological advances, should combine to make the export market attractive within the next ten years. Competitive power costs and a reduction in the fossil fuel glut, plus the expected growth in power needs, should turn the trick."

"Will improve greatly," was one optimistic comment; "still appears promising although hardly likely to be of large over-all dollar volume," said another. "Do not foresee improvement until domestic use of nuclear power is on normal business basis and we have developed reactors of characteristics suitable for export market," was another view. "We should write off the export market except for engineering and fuel, and unless our components are (a) patented, (b) better, or (c) cheaper," said still another.

Soviet Bid to India Shuns Competition

A Russian offer of broad assistance to India's atomic program renounces strict control and inspection over the power reactor Russia would furnish India, but sets the remarkable condition that India not invite worldwide bids for the reactor, as she had planned to do. The Soviet offer also covers help in exploitation and utilization of atomic minerals, training of Indian technicians in Soviet installations, and aid in isotope production. The reactor is offered on easy credit at low interest. India's Homi Bhabha is going to Moscow May 15 for a month to study the offer. Meanwhile talks in Delhi with a U. S. AEC team under International div. head Myron Kratzer are going "extremely well."

Economic Military Power Arrives But Pentagon Hesitates

On April 1 the most comprehensive study ever carried out on stationary power costs for the military was due to arrive at the Joint Committee on Atomic Energy. It was expected to show conclusively that nuclear power-and/or-heat plants have a clear economic advantage over conventional plants at several military sites abroad.

Ordered by JCAE and conducted for AEC and the Army (representing all military services) by Kaiser Engineers, the report's arrival at the Capitol on the first of April could hardly be more timely. For the Army, Navy and Air Force—for whom AEC and the Army Corps of Engineers have been developing a series of reactors under the Army Nuclear Power Program (NU, Feb. '59, 46)—are refusing to buy the plants they themselves asked to be developed.

The three military services are refusing to schedule the construction of nuclear field plants, beyond one in Alaska and one in Greenland under construction, because of their higher first costs. The services agree that nuclear plants are cheaper over their lifetime than conventional plants at certain high-cost sites. But conventional plants have gotten the nod in the Pentagon budgets for fiscal '60 and '61 because their lower first costs fit more easily into year-to-year budget ceilings. The service budgets for '62 are now in early stages of preparation.

Budget Pressure Again

Informed sources say the most formidable barrier to a swing to nuclear power has been the Administration's immovable decision to balance this year's budget and to show a substantial increase in fiscal '61, which begins July 1. In nailing down this favorable budget position, the White House and Budget Bureau have handed down spending ceilings to each government agency. With dollars saved in selecting conventional plants over nuclear, the services can schedule other projects they would otherwise have to forego.

Two industry witnesses identified the problem (and their analyses have been endorsed privately by Pentagon officials) at JCAE's "state-of-the-atom" hearings in late February:

J. Donald Rauth, Martin Co.: "Initial costs of nuclear installations are higher, but a fair economic comparison must also consider the cost of generating power over the expected life of the plant. Since military budgets are authorized annually, it is often hard to argue for long-term savings. Also, since nuclear power plants are not linked directly to specific, operational missions (as are missiles and submarines), they are not likely to be treated with the same degree of urgency.

"Nevertheless, we are convinced of the economic soundness of this solution to remote military power needs; and we feel that the experience gained from further operational tests should produce an expansion of orders for small nuclear power plants."

W. D. Leggett, Jr., Alco Products: "It is generally conceded that there are remote locations where the nuclear power plant provides the best logistic solution. There are geographical areas where the nuclear power plant even in its present state of development is economically competitive because of the very high cost of delivering fossil fuel. . . .

"There is an understandable reluctance on the part of the military forces to include in a facilities budget, which as the Congress has been aware has always been limited, an item for a nuclear power plant entailing a capital expenditure higher than required for conventional type of power plant."

Kaiser Study

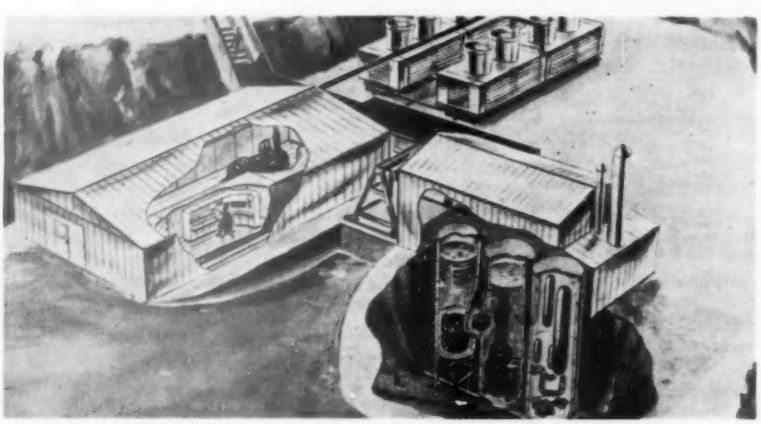
The Kaiser study will show, on the basis of the nearest thing to unbiased cost figures ever collected for stationary military power, that the present tendency to bypass nuclear power because of budget pressures smacks of false economy. Kaiser selected ten sites from a much longer list furnished by the three services (sites needing new or incremental plants in the 5–40-Mwe range); each site was then carried through a detailed economic comparison as between fossil and nuclear fuel. For several, according to informed sources, the economic advantage in nuclear plants will be unassailable.

Thus, economic power has "arrived" for military stationary use but no one is buying. Leggett and some in the Pentagon feel that a special financial incentive—for example, something equivalent to a capital subsidy—may be needed to get around the first-cost problem.

But this approach appears to have less chance of prevailing than the mounting evidence that nuclear power is simply cheaper than conventional installations.

Savings in Antarctica

Sen. Henry M. Jackson (D-Wash.) disclosed last month that the Joint Committee on Atomic Energy has figures indicating that nuclear plants built in the Antarctic could produce heat and electricity at 25% of the cost of conventional plants—over a 20-year plant lifetime. Jackson said fuel oil is $1–$3/gal at McMurdo Sound and between $7–$10 at two less accessible stations. He suggested that JCAE include reactors for these bases in AEC's fiscal '61 construction authorization bill.



PM-1 AS IT WILL LOOK in the summer of '61 when Martin Co. completes it for the Air Force at Sundance, Wyo. PM-1 will produce 1 Mwe and 7-million Btu/hr heat. Core, at bottom of middle tank (lower right), is flanked by spent-fuel tank (left) and tank containing steam generators and pressurizer (right). At top center: two condenser banks. At left: housing for steam turbine, generator, controls. PM-1 core went critical March 17

REACTOR NEWS

CALIFORNIA UTILITIES NEARING DECISION . . .

Latest reports from the West Coast on the plans of Pacific Gas & Electric and Southern California Edison to build nuclear power plants in the 300-Mwe and larger class (NU, March '60, 21): "Give us some more time—we're working," said a spokesman for PG&E; "We are in process of completing our engineering analyses right now," said an Edison official.

. . . AND FLORIDA GROUP ALSO

Florida West Coast Nuclear Group plans to reach a decision by Sept. 1 on whether or not to build its planned 50-Mwe heavy-water-moderated, gas-cooled reactor east of Tampa. If power cost can be shown to be no more than 150% of conventional power cost, FWCNG will go ahead. Meanwhile it has applied for a construction permit, just to be ready to move ahead without delay.

YANKEE 4–6 WEEKS AHEAD OF SCHEDULE

Despite some bad breaks on component supply (e.g. the reactor vessel was shipped 3½ months late), Yankee is 4–6 weeks in advance of schedule. Target date for starting to load fuel had been Aug. 1, with criticality to follow two weeks later, and low-power testing to occupy the succeeding four weeks. Now, if the present advance can be maintained—and site construction men think it can—the 134-Mwe reactor may already be up to medium power range by Aug. 1.

GCRE-1 CRITICAL IN IDAHO . . .

AEC's Gas Cooled Reactor Experiment, 26th reactor completed at the National Reactor Testing Station in Idaho, has gone critical. Not to be confused with AEC's Experimental Gas Cooled Reactor (EGCR) at Oak Ridge, GCRE is the first unit in development of a mobile nuclear power plant for the Army and a major step toward ML-1, a mobile closed-cycle gas-turbine reactor plant (NU, March '60, 26). GCRE is water-moderated and nitrogen-cooled, will generate 2.2 Mwth, no electricity. Aerojet-General has the prime contract (awarded October 1956); Battelle helped design, and M&C Nuclear built, the highly-enriched cermet core. The UO_2–stainless-steel cermet is clad in stainless plates; each element consists of 12 curved plates assembled into four concentric cylindrical tubes.

. . . AND SPERT-2 TOO

Idaho's 27th, SPERT-2 (Special Power Excursion Reactor Test) went critical 18 days later, March 12. The $4-million unit for reactor-safety research was built by Paul Hardeman, designed by Phillips.

DRESDEN TWO-THIRDS LOADED

Critical testing of the Dresden reactor was carried out at 144, 256 and 320 element loadings: no problems. Late this month or early in May loading and low-level tests should be completed; then low-power tests with the reactor head bolted on, and first steam production, can begin.

DAVISON TO FABRICATE A U-233 CORE . . .

In the first large-scale fabrication of U^{233} by private industry, Davison Chemical division of W. R. Grace will fabricate U^{233} fuel for the critical assembly of the Advanced Epithermal Thorium Reactor that Atomics International is developing for Southwest Atomic Energy Associates (NU, Sept. '59, 29). U^{233} presents special fabrication problems because of the rapidity with which activity increases as it is worked. Davison will get ~25 kg from AEC in 2-kg shipments; this will be converted to oxide and made into 1,200 aluminum-clad platelets ($2 \times 2 \times \frac{1}{8}$ in.), each containing ~20 gm U^{233}. Fabrication of each shipment must be completed in three days.

. . . AND OTHER FUEL, COMPONENT AWARDS

M&C Nuclear got the contract for 36 MTR-type elements to fuel the pool research reactor AMF is building for the Austrian AEC at Seibersdorf near Vienna. . . . C. F. Braun & Co., Alhambra, Calif., got a $677,200 contract for two steam generators for the Oak Ridge Experimental Gas Cooled Reactor. Each will take 1040° F, 300-psi helium on the shell side and produce 128,000 lb/hr of steam at 900° F, 1250 psi. . . . Sylcor has obtained a contract to provide a more reactive core loading for the Ispra (CP-5 type) research reactor. The MTR-type elements are 90% enriched, not 20% as the first core.

MISHAP AT HANFORD

A small fire, starting from an electric arc welder, resulted in spread of radioactive particles in two rooms and a corridor of a Hanford chemical separations plant on Feb. 25. Six workers were exposed to external contamination but all were wearing masks and coveralls. Damage was minor; plant operation was not interrupted.

***SAVANNAH* CORE TESTED; SERVICER CHOSEN**

Cold critical experiments on NS *Savannah's* core are being run in a critical facility at Babcock & Wilcox's Lynchburg labs. The tests have already confirmed nuclear design and engineering calculations, and will cut some time from the ship's dockside testing period. . . . Todd Shipyards Corp.—already at work building *Savannah's* maintenance barge, NSV *Atomic Servant* (NU, Aug. '59, 19)—has been chosen for another *Savannah*-support role. Its proposal for maintaining and servicing the pioneer nuclear ship was picked—from among eleven—by Maritime Administration as basis for negotiations. Requirements include repairs and refueling of *Savannah*, provision of spare-parts storage, decontamination area, provision (if required) of a spent-fuel pit, and berthing and maintenance of *Atomic Servant*.

AM-STAN SELLS ARGONAUT TO AUSTRALIA

Advanced Technology Laboratories division of American-Standard is building a UTR-10 Argonaut-type research reactor for the Australian Atomic Energy Commission.

HEARINGS, HEARINGS

The Parr Shoals, S. C. (Carolinas-Virginia) reactor got a clean bill of health from AEC's hazards evaluation staff at an AEC hearing on construction permit . . . Yankee attempted an administrative shortcut (result not yet known) by asking for a hearing to get approval of the "technical specifications" of the reactor—operating procedures and limits as well as design and performance specs. In effect Yankee is seeking a finding now that the reactor, as built, will be safe when completed; the hope is to avoid possibility of delay in getting the operating license. . . . Hearings scheduled in late March and early April include ones on a construction permit for the Big Rock Point, Mich., reactor (Consumers Power Co., General Electric); on the safety of the Hallam, Neb., plant (Consumers Public Power District, Atomics International); and on modifications to General Electric's 5-Mwe Vallecitos reactor.

WORLD NEWS

U. K. Cuts U Price, Gives Burnup Guarantee

Britain has slashed its price for natural uranium by 15%. Authoritative sources confirmed to NUCLEONICS that the Atomic Energy Authority will sell U at about $47,500/ton to the Japan Atomic Power Co. to fuel the 150-Mwe reactor General Electric Co. is building at Tokai Mura. Previous price was $56,000. Confirmed also was existence of a fuel burnup guarantee in the form of a sliding-scale arrangement for repurchase of irradiated fuel by AEA during the reactor's first ten years of operation. Repurchase price will vary according to the fuel's variance from an agreed (but not disclosed) burnup figure.

Site Dispute Threatens SELNI Plant

A loud dispute has erupted in Italy's coastal province of Liguria over the site chosen by the SELNI utility group for its 165-Mwe Westinghouse pressurized water reactor (NU, Feb. '60, 26). The site at Vallegrande near Moneglia, between the sea and a ring of mountains, is naturally well shielded (only access is by a disused railway tunnel); but the mayors of nearby towns and the local press are up in arms, crying that the safety of the famous Italian Riviera is at stake, that the plant will drive away tourists and radioactive waste kill the fish. SELNI leaders have taken pains to explain the plant's safety, with press conferences and television appearances, but have failed to stem the tide of what the atomic industry is calling a "nuclear psychosis." Meanwhile the Ministry of Industry has not yet ruled on use of the site.

Harwell Scientists 'Withdraw Their Labor' One Day

More than 1,100 top British scientists staged a one-day token sit-down at Harwell in protest over pay, status and administrative grievances. Forbidden as civil servants to strike, they took one day of annual leave March 1 as "a warning to the Authority that there is a limit to which even highly-placed scientists can be pushed." Behind this demonstration of disaffection by a large part of the cream of British scientific talent is a strong feeling that scientific workers have inadequate status as compared with administrative ranks.

U. S. in Data Swap on Dragon, Peach Bottom

The Dragon Board of Management approved a proposal for exchange of information with AEC on Dragon—the $38-million high-temperature gas-cooled reactor that 12 OEEC countries are building at Winfrith Heath, England—and the similar Peach Bottom, Pa., reactor General Dynamics is developing in the U. S. Construction on Dragon was to get underway in late March.

Merger of British Groups Fails

Merger negotiations between two British consortia—the General Electric–Simon Carves group and Atomic Power Constructions Ltd. (NU, Nov. '59, 29) have been terminated, because existing GEC ties abroad proved impossible to integrate with a general collaboration program. The news comes only two months after another merger of two others of Britain's five consortia was effected (NU, Feb. '60, 26).

Spain Opens Uranium Plant

First link in Spain's program for an independent nuclear industry, the country's first uranium processing plant was officially opened. The $1.85-million plant at Andujar near Seville will have an ore-processing capacity of 200 tons/day, or about 60,000 tons/year. It was built entirely by local scientists and engineers using 85% Spanish equipment. The plant is near Spain's first economically-exploitable uranium mines at Santa Maria la Cabeza and Cardeña. Storage facilities will hold 40,000 tons of ore. The Junta de Energia Nuclear says the cost of ore reduction will compare favorably with international prices, freeing Spain from import dependence.

BelgoNucleaire Building Pool Unit; It's BR-O2 Critical

A 15-kw pool research reactor is being built by the Belgian industrial group BelgoNucléaire for Ghent University, for completion this year. BelgoNucléaire is also collaborating with Sweden's Atomenergi A.B. on improvements to Sweden's R1 reactor. . . . What went critical in Belgium Jan. 14 (NU, Feb. '60, 26) was not BR-2 but a full-scale critical experiment for it, designated BR-O2. BR-2 itself, the high-flux testing reactor, is to go critical this fall. It was originally scheduled to be completed by the end of 1958 (NU, Feb. '56, 13).

Japanese Reactor Not Cause of Shutdown

The incident at Japanese Research Reactor No. 1 that resulted in its shutdown in December (NU, Feb. '60, 26) originated in radioactive manganese-56 being spilled as it was taken from an experimental hole, NUCLEONICS learns. It was unrelated to operation of the reactor.

U. K. Research Reactors: Herald, Consort, and a Sale

A new research reactor, Herald, went critical at Aldermaston Atomic Weapons Research Establishment. Built by AEI–John Thompson and adapted from the company's Merlin pool reactor, Herald has tank cooling (like the Oak Ridge Research Reactor). It will operate at 5 Mwth continuous, have 10^{14} fast-neutron flux, be used for radiation damage studies on reactor materials. . . . General Electric Co. will market for $140,000 a new 10-kw water-moderated research reactor called Consort, designed jointly by the GEC–Simon Carves group and the Nuclear Power Group. The core is located only 10 ft below water level in a well, but movable 2½-ft concrete shielding trolleys cover the well in operation. The core is made up of 20–24 standard MTR-type elements. Consort is designed primarily as a neutron source, has a thermal flux of 3×10^{12}, fast flux of 2×10^{12}. . . . Holland's Reactor Center has ordered a Jason (Argonaut-type) 10-kw reactor from Hawker Siddeley Nuclear Power Co. (NU, April '59, 26) for $140,000.

Japanese Jottings

Japan's biggest utilities have completed studies of their power needs and the phasing-in of nuclear power; observers see them moving in the direction of buying U. S. enriched-fuel plants. Tokyo Power Co. and Kansai Power may place orders with Westinghouse and General Electric before year's end, these sources say. . . . The Tokyo Atomic Industry Conference (TAIC—the Hitachi group) has established the Tokyo Atomic Industry Research Co., capitalized at $1-million. It is starting at once to build a 57,750-ft² plant at Kawasaki on Tokyo's southern edge, where it has already started to build a 100-kw tank reactor, and where the Nippon Atomic Industry Group (Toshiba-Mitsui) and the Tokyu Atomic Power Group are building a pool and a Triga reactor respectively. Kawasaki is thus becoming private industry's nuclear research capital, parallel with the governmental center at Tokai Mura.

NEWS IN BRIEF

Starr and Gavin Promoted to Presidencies

Chauncey Starr and James M. Gavin have been elected to the presidencies of, respectively, the Atomics International div. of North American Aviation and Arthur D. Little, Inc. Starr's is a new post; he had been general manager at AI (Starr continues as a vice-president of NAA). Gavin succeeds Raymond Stevens, retiring after 40 years at ADL but remaining partially active as chairman of the executive committee. AI also named four men to vice-presidencies: W. L. Sequeira, administration; A. B. Martin, sales; Sidney Siegel, technical; and J. J. Flaherty, planning.

Gavin

Starr

Massachusetts, New Jersey Planning Atomic Parks . . .

The States of Massachusetts and New Jersey have plans to aid the nuclear industry in the establishment of industrial parks. Massachusetts's legislature has been conducting hearings on the creation of an Atomic Energy Authority to direct the establishment of a park at Camp Edwards in the Cape Cod area. New Jersey has held discussions with AEC on the possible location of a park in South Jersey, including a dock area for refueling nuclear ships. New York had announced earlier hopes for a similar nuclear complex (NU, Jan. '60, 27).

Massachusetts legislators said there was a fairly good chance of getting approval this spring of a bill creating a state Authority with an initial budget of $200,000 to get the Camp Edwards project started. Atomic Energy Coordinator Raymond I. Rigney said several firms have expressed interest in locating at the site.

. . . And New York and Texas Take Nuclear Steps

New York Governor Nelson Rockefeller was expected to sign into law by the end of March a bill authorizing the state's Office of Atomic Development to acquire sites for the concentration and storing of radioactive by-products and the construction and operation of a test reactor (NU, Jan. '60, 27); and to permit cooperation with the federal government in the regulation of nuclear activities. The bill also permits the Office to take preparatory steps toward the location in the State of a port facility for servicing nuclear ships . . . Texas Governor Price Daniel has created a 24-member Committee on Atomic Energy to advise him and private and public groups on nuclear development and regulation. Chairman is Dallas attorney Frank Norton.

AEC Rejects 12 "Horserace" Bids, Reviews Program

All 12 proposals in the most recent round of AEC's "horserace" program for evaluation of new-reactor concepts have been rejected. The proposals were made at end-August last year and rejected Feb. 26; two new proposals came in for the latest deadline, Feb. 29. AEC officials said the program (NU, Oct. '59, 22) was being continued for this latest round, at least, until Reactor Development Director Frank Pittman reviews industry's desire for continuing it. Pittman is said to feel that the semiannual bidding procedure may entail unfair bid-preparation expenses for industry; others in the Division feel that industry wants the program continued because it provides a formal forum within AEC for considering new ideas. The 12 rejections (and reasons):

American Standard (2). A re-usable fuel-cladding reactor concept (mechanical design problem and doubtful economic gain). Also a proposal to proceed with a substantial program on its mercury-cooled breeder to which AEC had already given $150,000 (restrict current effort, for immediate future, to physics work of about $50,000).

Burns & Roe (2). Molten-fluoride-fueled reactor system (no clear economic gain). Also a gaseous-fueled reactor (deferred).

Internuclear Corp. Automatic boiling column reactor (deferred because AEC is doing related work on heat flux-versus-steam quality).

Ford Instrument. "Nuclo-thermionic," direct-conversion concept (deferred pending further development in Los Alamos' direct-conversion program).

Paul N. Garay. Throw-away reactor (no organization to conduct a program, plus fact that Oak Ridge did similar work on a nuclear-gas engine some time ago).

Marquardt. Nuclear steam superheater reactor (deferred because of existing superheat program).

Neutron Products, Inc. Heterogeneous, water-cooled reactor using unclad fuel (no clear economic incentive nor materials-technology advance).

Reaction Motors. Fission plasma reactor for direct conversion (too many basic questions to resolve in both nuclear and non-nuclear areas).

Westinghouse. Basic studies of thoria and urania slurries (deferred because work would, in part, duplicate work underway at Oak Ridge National Laboratory).

General Electric. Sodium-graphite modular concept (GE and AEC agreed to drop this).

AEC Sends Group to Alaska on Plowshare Project

A three-man contingent representing AEC began a round of visits to Alaskan villages last month to explain the Commission's proposed project for blasting out a harbor on the northwest coast with nuclear explosives. The detonations would include one 200-kiloton and four 20-kiloton explosives detonated simultaneously. The Alaskan experiment is one of several under study under Project Plowshare and is known as Project Chariot. Further environmental studies will be made at the proposed site this year and the experiment itself will not be scheduled before 1961—its schedule depends both on feasibility and U. S. nuclear-test policy at that time. . . . AEC has announced a start on site preparation—to take a year—for a Plowshare experiment near Carlsbad, N. M. (Project Guome, a 10-kiloton salt-bed shot).

ACRS Against Pt. Loma for Process Heat Reactor

AEC's Advisory Committee on Reactor Safeguards has advised against the Pt. Loma (San Diego) site for the process heat reactor for saline water conversion (NU, March '60, 23). Reasons: unfavorable meteorology, and high population density "aggravated by recreational and fisheries aspects." AEC and Interior still want the site for the reactor; Navy, which controls it, still feels it would conflict with its plans to build a Polaris-servicing facility 0.8 mi away. The situation is expected to be resolved at Cabinet level.

FPC Finds Power from NPR would be Economic

A study just completed by the Federal Power Commission shows that conversion of the New Production Reactor at Hanford to make power (as well as plutonium) would be economically sound. FPC says the nuclear power would be no more costly than fossil or hydro power if U costs drop as forecasts and Pu stays at $12/gm.

RADIATION NEWS

Six-year Programs Okayed for Food Irradiation

A new Army Food-Irradiation Program neared formal announcement last month after getting the informal approval of Richard Morse, Army research-and-development chief (NU, March '60, 23). Morse has approved a 6-year program aimed chiefly at perfecting radiation-sterilization of a few foods, but not neglecting pasteurization nor nonfood items (clothing, etc.).

Meanwhile, the Interdepartmental Committee on the Radiation Preservation of Food was preparing to announce another 6-year program keyed to commercial food irradiation and managed by AEC. $500,000 has been budgeted by AEC for the first year (fiscal 1961) and a total of $5-million has been budgeted through '66.

The Army's new research center (successor to Lathrop, Calif.), will include an electron linear accelerator built by Varian Associates, a 1-million-curie cobalt-60 irradiator and a $400,000 support lab. Site will be selected after a thorough review of the needs of both the Army and civilian programs (the latter is expected to make use of the Army's facility, as well as any facilities, such as X-ray machines, that may be ordered to support the civilian effort). Varian has done 80% of the work on a 24-Mev linac for the Army and will scale it down to 12 Mev at a cost of $400,000; $1-million is available for the cobalt-60 source.

Martin Announces Two Isotopic Power Projects

Two projects looking toward an expanding market for isotopic power sources have been proposed by Martin—one on its own, the other jointly with Air Reduction Co. Martin has had on file with AEC since last summer a license application for construction and operation of an $800,000, 4-cell laboratory designed to handle megacurie quantities of strontium-90. To be located at Martin's Middle River, Md., headquarters, the glove-box type facility (with a single all-around shield to permit cell-to-cell passage) would be used for the fabrication and test operation of direct-conversion generating devices of the type under construction for AEC and the U. S. Weather Bureau (NU, Jan. '60, 27). The facility would handle more radioactive material, by far, than any ever proposed for private operation. AEC is conducting a specially rigorous safety review and will not issue a license until interested parties have been given an opportunity to comment.

With Air Reduction, Martin is studying the feasibility of building a plant to separate Sr^{90}, cesium-137, cerium-144 and promethium-147. Preliminary studies indicate that Sr^{90} could be produced at 35–50 cents/curie, or one-tenth current AEC prices. The project is a long-range one which is heavily dependent on government programs for using isotopic-power devices in substantial quantities.

Danes Get 15-Mev Electron Linac from Varian

The Danish Atomic Energy Commission was expected to begin installation this month of a 15-Mev electron linear accelerator built by Varian Associates for research in food irradiation, chemistry, physics and medical sterilization (bone grafts, etc.). Power in the beam is 5 kw at 5 and 10 Mev, with peak current exceeding 600 milliamps. A Varian electronic vacuum pump replaces the conventional oil diffusion pump and results in a cleaner vacuum and substantially reduced maintenance costs, Varian said. A beam bending and programmed scanning system permits uniform irradiation of items passing through the beam on a conveyor. The machine can pasteurize 60,000 lb food/hr at a half-megarad dose. A food-irradiation linac designed by Varian for the U. S. Army Quartermaster Corps is about 80% complete but awaits word from Washington—which is expected to come soon—on completion.

Radiation Notes: Sales, Acquisitions, Canadian Lab

Nuclear-Chicago said February was its best month in history for both sales and orders; final figures on the quarter ended Feb. 29 were also expected to be record-breaking . . . **American Electronic Laboratories**, Philadelphia, has taken a year's option to buy a majority interest in **Nuclear Research Corp.**, Southampton, Pa., makers of gamma gauges and other nucleonic instruments. . . . **Raychem Corp.**, Redwood City, Calif., has acquired **Bentley-Harris Mfg. Co.**, Conshohocken, Pa., producers of fiberglass sleeving; Raychem also reported a 106% increase in sales for the year ended Dec. 31, with profits down from $68,000 in 1958 to $41,000 in 1959. . . . The Ontario, Canada, government has decided to build a $220,000 research lab at Toronto for measurement of radioactive fall-out.

HVEC Nears Biggest Order, Sets 50% Expansion

In a big month for High Voltage Engineering Corp.: 1. the National Bureau of Standards said it expected to order from HVEC the largest particle accelerator ever built by a private firm; and 2. HVEC announced that it was expanding its Burlington, Mass., plant from 120,000 to 180,000 sq ft. The NBS order, which is predicated on Congressional fund approval for the machine (under $2-million, it is understood, but neither party is saying), would be the largest order in HVEC history. It is a 100-Mev high intensity microwave linear accelerator with 40-kw in the beam and capability to accelerate particles to 150 Mev. It would be installed in a new radiation physics lab at Gaithersburg, Md., which is scheduled for completion at end-1962. The lab will also house NBS' 50-Mev betatron, 180-Mev synchrotron and 1-Mev accelerator, plus a 3-Mev accelerator still to be ordered.

If Congress should fail to appropriate the funds now being sought for the 100-Mev machine, NBS will reopen the project to interested bidders, including three unsuccessful bidders last summer: Applied Radiation, Hughes Aircraft and Varian Associates.

NSEC Establishes Scientific Advisory Group

A technical "board of directors" has been established by Nuclear Science and Engineering from among four scientific members of its board of directors, two outside scientists (including Merril Eisenbud, former manager of AEC's New York Operations Office) and two of its own executives. Chairman of the group, which advises the firm on long-range planning, staff capability and promising fields NSEC might enter, is Truman P. Kohman of Carnegie Tech. Other members: Glenn P. Seaborg, Univ. of California, and Manson Benedict and Charles Coryell, MIT (these first four are also board members); Eisenbud; John H. Rust of the Univ. of Chicago; and Abraham Edelmann and Paul Kruger, NSEC vice-presidents.

AEC Coordinating U. S. Papers for Copenhagen Meeting

Papers for the Sept. 6–17 international conference in Copenhagen, Den., on the "Uses of Radioisotopes in the Physical Sciences and Industry" are being coordinated by AEC's Office of Special Projects. The meeting is sponsored by the International Atomic Energy Agency.

ALSO OF NOTE . . .

The Cryovac div. of W. R. Grace & Co. formally announced last month that it was marketing 1 million lb/yr irradiated-polyethylene film wrap produced at a plant in Simpsonville, S. C. Cryovac is understood to have five General Electric resonant transformers, with an annual capacity of two million lbs of the new wrap. The firm is doubling this capacity, it said, and plans to establish production somewhere outside the U. S. late next year. Cryovac said the wrap has been okayed for food use by the federal government.

EBWR returned to criticality last month following completion of modifications to permit it to go to 100 Mwth. The Experimental Boiling Water Reactor was scheduled to resume making power by month's end, but will be put through an extensive measurement program to identify precisely the nuclear effects of the structural modifications before the attempt to achieve 100 Mw is made.

Los Angeles Department of Water and Power is going after the 50–75-Mwe improved-cycle boiling water reactor on which AEC has invited bids due May 4. The big municipal utility is ready to match AEC's $10-million for the reactor with $10-million of its own for site and conventional equipment. It is now taking steps to acquire a site in the desert east of Los Angeles. Pasadena Municipal Light & Power Dept. is joining in the bid. A competing bid might come from Dairyland Power Cooperative.

U. S. Partners with Canada On Heavy Water Reactors

The U. S. is going into unprecedently tight partnership with Canada on heavy-water natural-U reactors. AEC is budgeting $5-million for research-development work in AEC facilities specifically directed to the two Canadian reactors of this type being built (NPD, 20 Mwe; CANDU, 200 Mwe). It will include work on fuels, components and design features, and use of AEC irradiation and testing facilities. Under the arrangement AEC and U. S. industry will get "all the engineering and economic information, including drawings, plans, specifications and all other technical data, developed under the Canadian heavy-water reactor program and all the rights to developments and patents" that it would have if AEC did the work, Chairman McCone told Congress.

NUCLEONICS Statistics of the Quarter

Costs of U. S. Civilian Reactors in Progress ($10³)†

	Total Cost of Projects	Costs, '59 4th quarter	Costs thru 12/31/59	Still to be spent
Power prototypes & experiments	742,700	51,391	287,615	455,085
—Research & development:				
AEC	130,986	7,516	60,156	70,830
Electric utilities	66,140	2,096	37,394	28,746
—Plant, equip't., fuel fabrication:				
AEC	133,553	8,141	27,047	106,506
Electric utilities	412,021	33,638	163,018	249,003
Savannah propulsion plant	26,250	2,012	11,497	14,753
Research & test reactors	101,786	6,903	59,255	42,531
AEC	60,833	4,966	30,731	30,102
Other govt. agencies	14,649	332	12,168	2,481
Manufacturers & universities	26,304	1,605	16,356	9,984

	Latest month	Month ago	Year ago
Nuclear Contracts *—			
Contracts awarded for public projects ($10³)	3,658	1,926	8,885
Proposed construction, privately-owned ($10³)	0	1,000	23,000
Contracts awarded, private work ($10³)	1,306	0	0
Backlog of private projects ($10³)	287,549	287,549	259,549
Isotope Use †—			
Applications for isotope use	608	442	655
Cumulative total of isotope users	5,520	5,572	4,847
ORNL shipments (curies)	16,444	5,213	3,904
Public and private export shipments	329	539	107
Employment †—			
AEC employment	6,647	6,642	6,687
Construction and design contractors' employment	9,730	9,668	10,167
Total operating contractors employment	103,908	104,141	103,908
Production workers	51,176	51,278	51,839
Research and development employees	48,092	47,700	46,282
Miscellaneous workers	4,640	5,163	5,787

U. S.-built Reactors ‡—

	Operating	Building	Contracted
Power, domestic	1	9	7
Power, for export	0	3	2
Power experiments and pilot plants	6	5	2
Military and naval	21	41	4
Research and test, domestic	67	20	52
Research and test, for export	18	21	3
Total	113	99	70

Foreign-built Reactors ‡—

Power, domestic	17	23	15
Power, for export	0	3	1
Research and test, domestic	38	8	13
Research and test, for export	8	6	1
Total	63	40	30

* From *Construction Daily*, a McGraw-Hill periodical † From AEC ‡ NUCLEONICS figures

DOUBLES ANALYZER USEFULNESS*

makes previously impractical experiments routine

RCL's amazing new Spectrum Stripper® records the analyzer's entire memory content on magnetic tape within 10 seconds. This data can be stored until needed and then played back into the analyzer. As the data is played back, it can be added to or subtracted from the new data in the memory in its entirety or in fractions greater or less than one.

The Spectrum Stripper® is a new innovation whose full capabilities and application possibilities have not yet been determined. Here are a few typical applications. You probably can think of others.

CUT EXPERIMENT TIME IN HALF

In experiments involving background subtraction the Spectrum Stripper® effectively halves experiment time and doubles the number of "working" channels in your present analyzer. Now, every channel can be used for data accumulation. Background is accumulated beforehand and stored on tape. A single background accumulation can be subtracted from many experiments of different time lengths (i.e. if two hours of background are stored on tape, 150% of this—3 hours—may be subtracted from a 3 hour experiment and 50%—1 hour—may be subtracted from a separate 1 hour experiment).

IDENTIFY HIDDEN PHOTOPEAKS

The Spectrum Stripper® enables you to subtract dominant photopeaks from complex spectra, thus revealing normally indistinguishable low activity photopeaks.

RUN CONSECUTIVE STUDIES

The Stripper's 10-second "dump" time permits consecutive accumulations even when normal print or pen time cannot be tolerated. This taped data can be played back into the memory later and then printed out.

Fill out coupon below for complete specifications

Keep abreast of new products, applications and techniques in the nuclear instrument field. Read the RCL COUNTER. If you are not now on our mailing list, check RCL COUNTER on the Coupon.

*Directly compatible with all RCL vacuum tube analyzers only. However, purchasers may modify it for use with computers and/or other analyzers.

RCL RADIATION COUNTER LABORATORIES INC.

5121 West Grove • Skokie, Illinois • U.S.A. • ORchard 3-8700

Radiation Counter Laboratories, Inc. / Department 150 / 5121 West Grove / Skokie, Illinois, U.S.A.

Gentlemen:

_____Please send me complete information on RCL Spectrum Stripper®.

_____Please add my name to RCL COUNTER mailing list.

NAME _____

TITLE _____

ORGANIZATION _____

ADDRESS _____

CITY _____ STATE _____

superb new null detector and dc microvoltmeter

Model 151 offers non-linear and linear ranges, 10^{-17} watt sensitivity, 2 x 10^{-13} ampere current sensitivity.

The new Keithley 151, incorporating a unique photo-conductive modulator of Keithley design, is useful wherever a suspension galvanometer can be used and where a galvanometer is not sufficiently sensitive, fast or rugged.

As a null detector, has five non-linear ranges as well as linear ranges. Non-linear ranges each cover three decades, with full scale sensitivities of 0.001 to 10 volts. Center 10% of the log scale is linear, permitting extremely critical readings near null.

As a microvoltmeter or dc amplifier, has eleven linear ranges in 1x and 3x steps from 100 microvolts to 10 volts full scale. Input resistance on all ranges is ten megohms, yielding a maximum power sensitivity of better than 10^{-17} watt. Currents as low as 2 x 10^{-13} ampere can be detected. Output of 10 volts at 1 ma full scale permits use as a dc amplifier with gains to 100,000.

Other Features. Greater than 60 db rejection to 60 cps ac signals; zero drift below 10 microvolts per day; short-term noise within ± 2 microvolts.

MODEL 151 has 10^{-17} watt sensitivity, 2 x 10^{-13} ampere current sensitivity.

SPECIFICATIONS

Ranges: 11 linear ranges in 1x and 3x steps, from 100 μv to 10 v f.s.; 5 non-linear ranges of 0.001, 0.01, 0.1, 1.0 and 10 v f.s., each covering three decades.

Accuracy: Linear ranges, ± 3% of f.s. Non-linear ranges, ± 10% of input.

Input Resistance: 10 megohms on all ranges.

Response Speed: On 100 μv range, 2.5-sec.; 1-sec. on all others.

Noise: Less than 2% f.s. on all ranges.

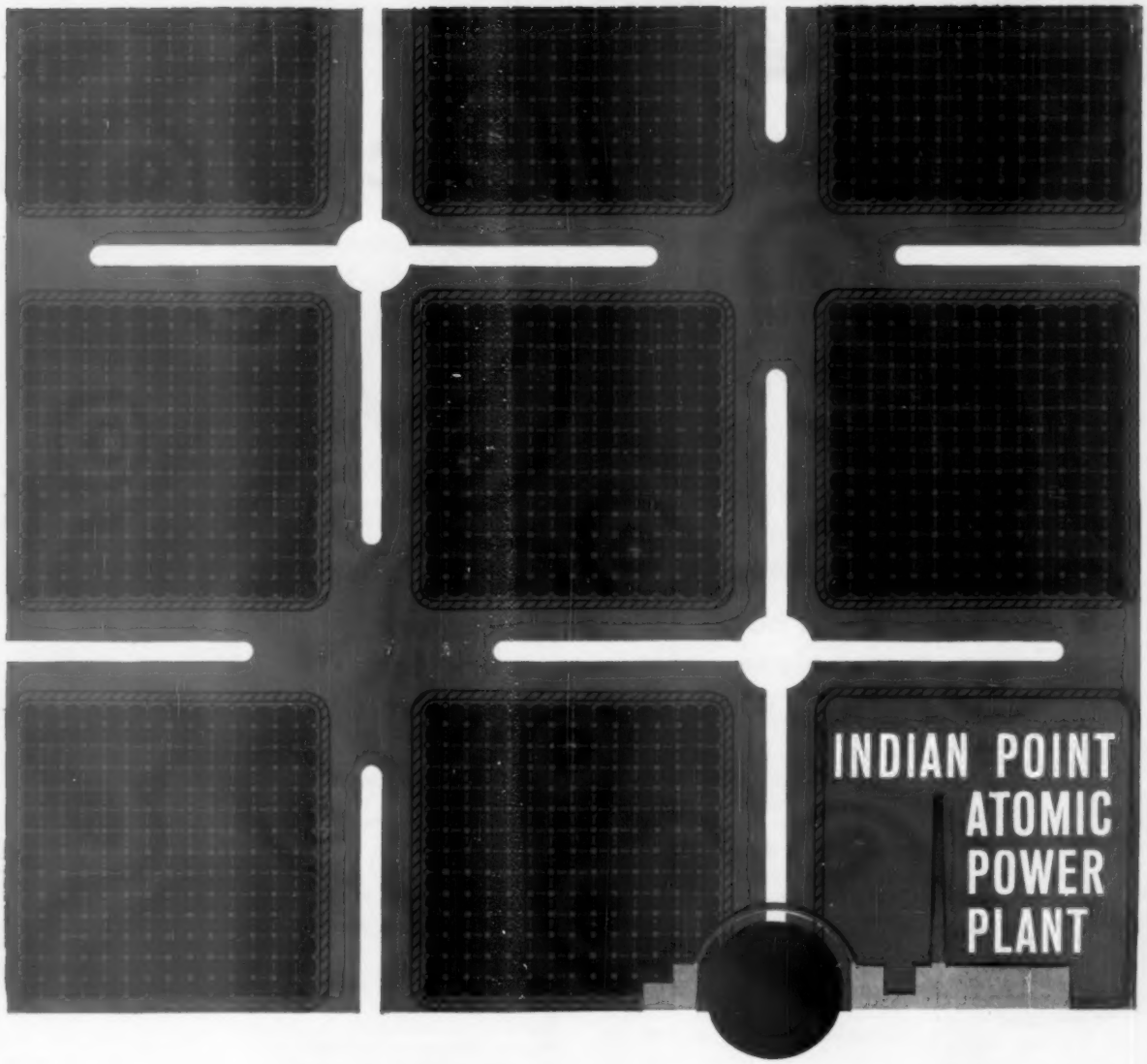
Zero Drift: Less than 10 μv per day after warm-up.

Output: 10 volts at 1 ma f.s.; resistance, less than 50 ohms.

Price: Model 151, Cabinet Model $395.00
Model 151R, Rack Model $385.00

For complete details, write:

KEITHLEY INSTRUMENTS, INC.
12415 EUCLID AVENUE CLEVELAND 6, OHIO



USING MALLINCKRODT URANIUM—93% ENRICHMENT

This reactor, as well as those of Commonwealth Edison Company and Yankee Atomic Electric Company, depends upon commercially produced nuclear fuels. The uranium loading of all three will be entirely or partly Mallinckrodt UO_2. ◆ The Indian Point reactor, designed and manufactured by Babcock and Wilcox Company, will use over 2000 pounds of Mallinckrodt UO_2 (93% enrichment). The balance of the fuel will be thorium oxide. This 275,000-kilowatt plant is owned by Consolidated Edison Company. ◆ Whether power, propulsion or experimental—domestic or overseas—Mallinckrodt has unequaled experience in producing uranium fuel materials. Mallinckrodt now offers over fifteen different forms of uranium compounds and metal . . . and can deliver completed fuel elements by working with metal fabricators. For consultation on your nuclear fuel problems, write or call Mallinckrodt.

MALLINCKRODT NUCLEAR CORPORATION • ST. LOUIS 7, MO.

THE WORLD'S FIRST AND LEADING PRODUCER OF NUCLEAR FUELS

Announcing... for ENGINEERS

The McGRAW-HILL Encyclopedia

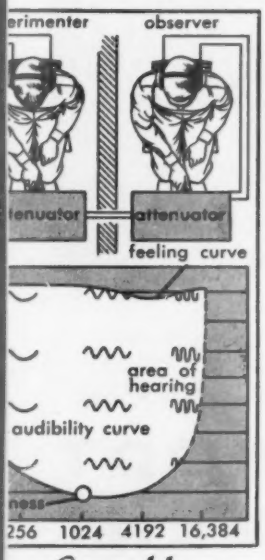
AVAILABLE FOR
A LIMITED TIME AT A

Special INTRODUCTORY PRICE

—at a prepublication savings. The introductory price of $159.00 saves $16 on the regular price of $175.00.

Low Monthly Terms Available

An unprecedented publishing achievement providing a complete reference work for the library of the engineer or scientist.



Superbly illustrated

The McGraw-Hill ENCYCLOPEDIA OF SCIENCE AND TECHNOLOGY contains more than 8000 drawings, charts, maps, photographs, and diagrams in both black-and-white and color. All were especially prepared by the finest craftsmen in technical illustration. They reinforce the written information — round out the complete, practical nature of the Encyclopedia.

TODAY's accelerated pace of technological developments demands a broader scientific background of the technical man. *No longer can a thorough knowledge of only his own specialty assure him of success.* A structural engineer must know about ocean currents before designing an off-shore oil-drilling platform ... a chemist needs a better background in electronics to make full use of instrumentation ... an engineer placing a cross-country pipeline requires knowledge of weather conditions ... a space scientist needs information on human physiological and psychological factors. The McGraw-Hill ENCYCLOPEDIA OF SCIENCE AND TECHNOLOGY is designed for needs such as these or others with which you may come in contact. *Nothing remotely like this has ever been done before.*

Your master reference to the world of science and technology

More than 7000 separate articles — many of them by men credited with performing pioneer research in their fields — provide unrivaled breadth of coverage — meet many needs within your range of interests and challenges. The articles range from concise definitions and basic foundation material, to the most modern developments, applications, and discoveries. So skillful and extensive is the cross-referencing that you could follow through to a basic education in virtually any technical or scientific field.

The work of world-renowned authorities

More than 60 Consulting Editors, aided by a distinguished Advisory Board, chose the most outstanding persons in each field to contribute to the encyclopedia. The names of the 2000 contributors read like a "who's who" in the pure and applied sciences — assuring you of the most informed view of each subject covered.

Leading contributors like Glenn T. Seaborg on the transuranium elements; Paul A. Siple on Antarctica; Selman Waksman on antibiotics; P. W. Bridgman on classical mechanics; H. E. Edgerton on deep-sea photography; recent Nobel Prize-winner Emilio Segre on the antiproton and antimatter; Krafft A. Ehricke on space engineering; and others of equal stature — provide you with brilliant coverage of any topic you seek out.

Unequalled in clarity

When you turn to the encyclopedia, you find that the articles explain and illustrate with the utmost skill, clarity, and accuracy. *Complete understanding*, in addition to factual information, keynotes the encyclopedia's approach. The style of treatment enables you to *quickly* get to the depth you want —comprehend the precise area and degree of knowledge you need — in any realm of technological interest or activity.

Completely indexed

The Index takes up an entire volume and runs to over 100,000 entries. Specific facts can be located quickly not only through the index, but also by means of the extensive cross-referencing of the 7200 articles.

• 15 volumes • over 2000 contributors • 9300 pages • 7200 articles

for SCIENTISTS for TECHNICIANS

# of Science and Technology

Now — *for the first time in the whole span of technological progress can you have conveniently and inexpensively available a universal reference of technical knowledge.* Never before have so many and such internationally known authorities been enlisted to provide you with the broader, more complete scientific and engineering background required by today's exploding technological developments.

MONUMENTAL in scope . . . prepared by over 2000 authorities . . . the McGraw-Hill ENCYCLOPEDIA OF SCIENCE AND TECHNOLOGY places at your command the basic concepts, terminology, and modern developments in *every area of engineering and science.* From aeronautics to zoology . . . from mechanical engineering to oceanography . . . from the atomic nucleus to the far reaches of outer space . . . *here is the whole sum of basic technical knowledge* distilled into 15 volumes for ready reference and ease of understanding.

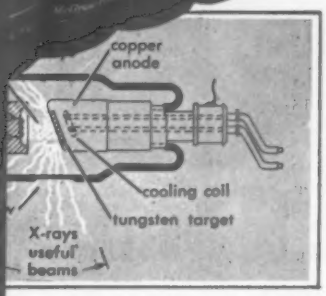
The McGraw-Hill ENCYCLOPEDIA OF SCIENCE AND TECHNOLOGY helps you attack more confidently the problems demanding knowledge beyond your particular field . . . enables you to bridge the gap between your specialty and countless other fields which grow ever closer to your own.

Special low prepublication price

To give the Encyclopedia as wide an initial circulation as possible — among the type of readers whose reactions are most important — a special low price, affording a savings of $16.00, is offered.

This offer is limited to orders placed before the Encyclopedia is published. In view of this, we urge you to mail the coupon for further information promptly. Your request now will reserve this price advantage for you, subject of course to your later examination and acceptance of the Encyclopedia.

Write to McGraw-Hill Encyclopedia of Science and Technology
327 West 41st Street, New York 36, N. Y.
Address department NU-4



Special techniques of illustration add unusual clarity

Up-to-date

The Encyclopedia reflects facts still in the news — the Van Allen Radiation Belts, the plans to probe the earth's crust to the Moho Discontinuity, artificial satellites, and much more. A YEARBOOK OF SCIENCE AND TECHNOLOGY will maintain the timely accuracy of the Encyclopedia.

Illustrations are accurate, complete; bring out essential details

EDITORIAL ADVISORY BOARD

Dr. Roger Adams
Dr. Joseph Barker
Dr. Detlev Bronk
Dr. George R. Harrison
Dr. Sidney D. Kirkpatrick
Dr. William Rubey
Dr. Edmund Sinnott

Consulting Editors

Dr. Philip Hauge Abelson
Prof. Theodore Baumeister
Dr. Frank A. Beach
Prof. Jesse Wakefield Beams
Prof. Firman E. Bear
Prof. Salomon Bochner
Waldo G. Bowman
Dr. Frank Brink, Jr.
Dr. Stanley A. Cain
Dr. Jule G. Charney
Dr. E. U. Condon
Prof. Albert G. Conrad
Dr. George W. Corner
Prof. Farrington Daniels
Dr. Lee Raymond Dice
Prof. Robert C. Elderfield
Dr. Katherine Esau
Harold Etherington
Donald G. Fink
Dr. Harvey Fletcher
Prof. Newell S. Gingrich
Prof. H. Bentley Glass
Dr. Julian R. Goldsmith
Prof. Harry S. N. Greene
Dr. John Anthony Hrones
Dr. Eric R. Jette
Dr. Joseph J. Katz
Dr. Friedrich Franz Koczy
Dr. J. Laurence Kulp
Frank K. Lawler
Prof. Richard C. Lord
Prof. Harold J. Lutz
Dr. Kirtley F. Mather
Harold B. Maynard
Dr. Ernst Mayr
Dr. Donald H. Menzel
Dr. Bernard S. Meyer
Rear Admiral Albert G. Mumma, USN (ret.)
Dr. Harold S. Osborne
Prof. Courtland D. Perkins
R. J. S. Pigott
Dr. K. R. Porter
Prof. C. Ladd Prosser
Prof. Lockhart B. Rogers
Dr. Howard S. Seifert
Dr. Frederick Seitz
Dr. Edward R. Sharp
Robert S. Sherwood
Dr. Thomas K. Sherwood
Prof. Robert R. Shrock
Laurence B. Siegfried
Dr. S. Mott Souders, Jr.
Dr. E. C. Stakman
Dr. P. D. Strausbaugh
Dr. Horace W. Stunkard
Dr. E. L. Tatum
Dr. Henry P. Treffers
Dr. C. B. Van Niel
Prof. William W. Watson
Prof. B. H. Willier
Dr. F. E. Wormser

Mail this coupon for full information

Department NU-4
McGraw-Hill Encyclopedia of Science and Technology
327 West 41st Street, New York 36, N. Y.

Please send me your Prospectus on the McGRAW-HILL ENCYCLOPEDIA OF SCIENCE AND TECHNOLOGY, with full details of your special price offer and budget terms for Prepublication Subscribers. (No obligation, of course. No salesman will call.)

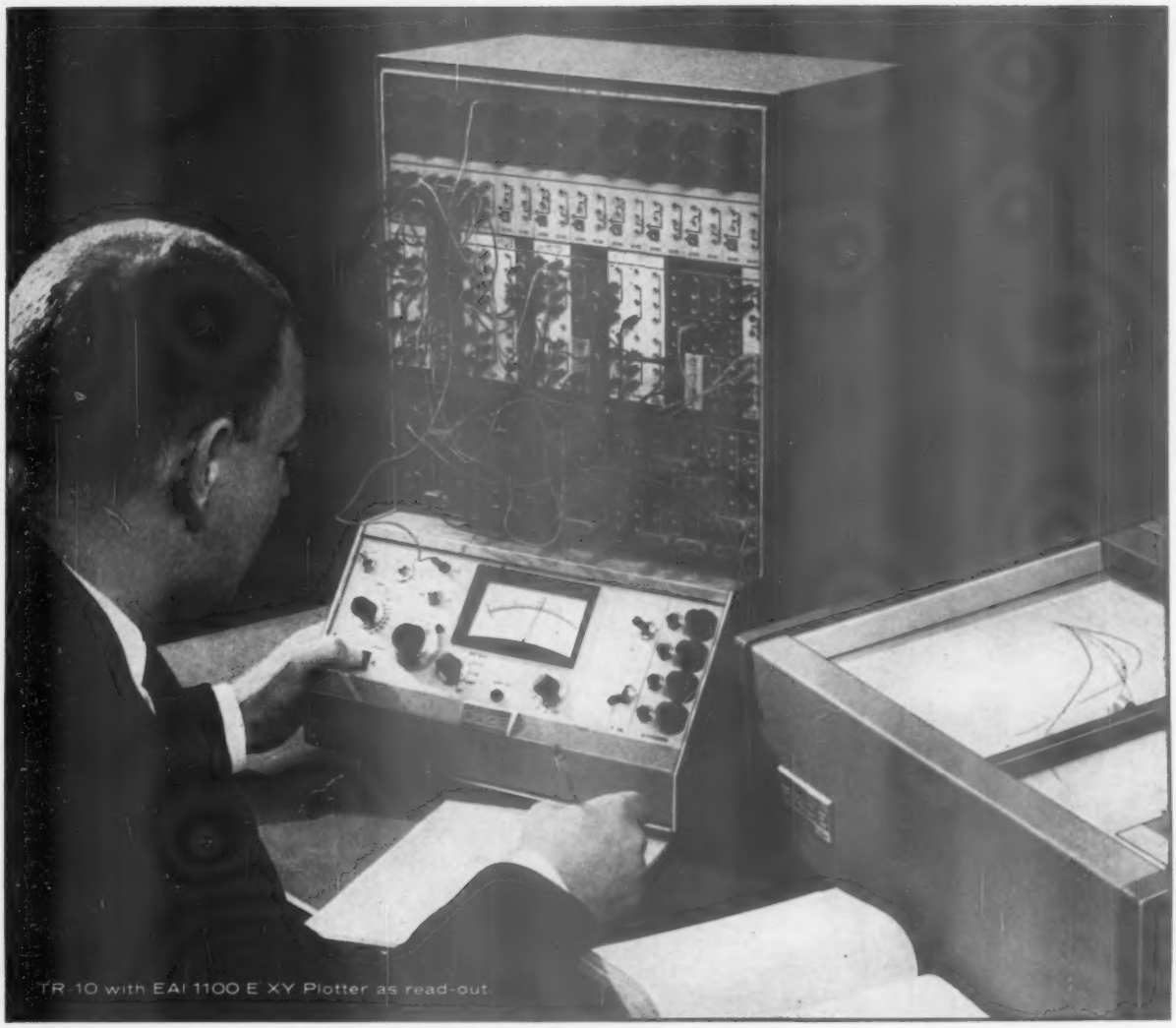
Name.....

Address.....

City.....Zone.....State.....

NU-4

• 8700 illustrations



THE *FIRST* ALL TRANSISTORIZED ANALOG COMPUTER

—basic model less than $4000

PACE® TR-10 Eliminates Drudgery—Gives New Insight Into Engineering Problems

This compact unit, 15″ x 16″ by 24″ high, is powered by 115 volts AC and can provide day-in day-out instant solution of your most vexing engineering problems. Even if you have never seen a computer before, you can learn to operate the TR-10 as easily as you learned to use a slide rule.

Simply turn a dial to feed in design parameters, and the computer provides an instant by instant, dynamic picture of the effect of each change. You can study the inter-related effects of heat, pressure, flow, vibration, torque or any variable, and visually compare one with the other. Engineering data comes alive – insight into how new designs will work is obtained easier, faster.

Because of its minimum size and low price, the TR-10 can become your own personal analog computer. You gain first-hand experience with the power of analog techniques, and convert more of your time to *creative engineering*. New ideas that were too costly to try before are now practical. You can design virtually to perfection and have a permanent, visual record of performance before building pilot models or prototypes. As a result, "cut and try" expense is reduced.

The same quality workmanship and design that has made Electronic Associates the world's leading producer of precision general purpose analog computers will be found in this new unit. Accuracy to ±.1 per cent. Modular construction allows you to select varying quantities of the following computing functions: summation, integration, multiplication or division, function generation, parameter adjustment, logical comparison.

For complete engineering data, write for Bulletin R-10-K

EAI ELECTRONIC ASSOCIATES, INC.
Long Branch, New Jersey

If your company is looking for experience in the extrusion and coldworking of nonferrous metals–particularly those having special characteristics such as high temperature resistance or low neutron absorption . . .

let's get together

. . . because we, at Wolverine Tube, have this kind of experience–have been working for a number of years in such special metals as zirconium, columbium, titanium, tantalum, molybdenum, etc. Our research and development facilities are among the most complete in the tubing industry, are entirely separate from our normal manufacturing operations, thus enabling us to devote full attention to your problems.

Important, too, is the fact that we are heat transfer specialists–have had years and years of experience in this field. We'll be happy to give you the complete story. Just write...wire...or call!

CALUMET & HECLA, INC.
CALUMET DIVISION
URANIUM DIVISION
GOODMAN LUMBER DIVISION
WOLVERINE TUBE DIVISION

In Canada:
CALUMET & HECLA OF CANADA LIMITED
WOLVERINE TUBE DIVISION
CANADA VULCANIZER & EQUIPMENT CO. LTD.
UNIFIN TUBE DIVISION

WOLVERINE TUBE
DIVISION OF
CALUMET & HECLA, INC.
17260 Southfield Road
Allen Park, Michigan
Manufacturers of Quality Controlled Tubing and Extruded Aluminum Shapes

PLANTS IN DETROIT, MICHIGAN AND DECATUR, ALABAMA.
SALES OFFICES IN PRINCIPAL CITIES

8573

PROCEED, DEFER OR MODIFY?

Kaiser Engineers can help you decide

Objective analysis is vital to sound decision on new power generating facilities. Feasibility studies, economic analyses and site evaluations are yours by an outside, impartial firm when Kaiser Engineers is selected to help you decide when, how and where to proceed.

These services are in addition to the design and construction of all types of power plants—nuclear, fossil fuel and hydro-electric—as well as other nuclear facilities.

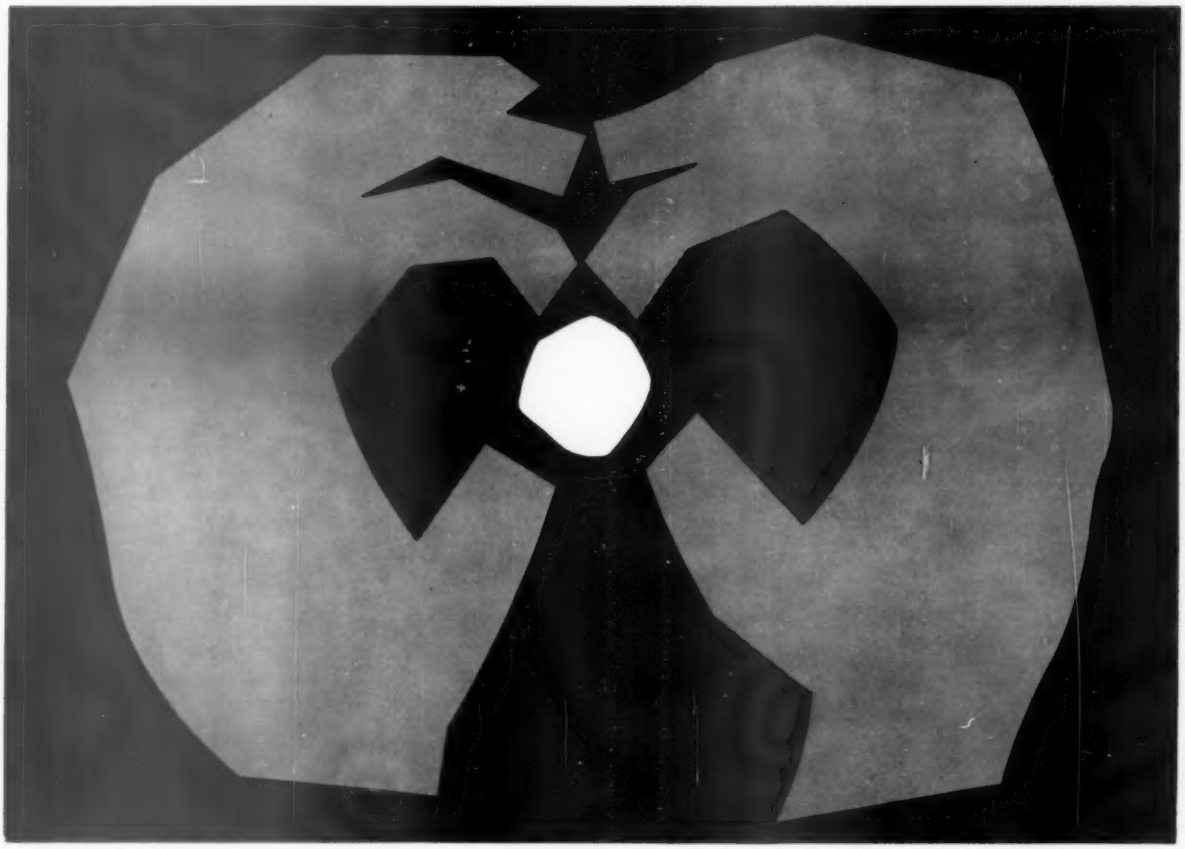
KE offers complete, one-company, integrated service from concept through construction—plus world-wide experience and the ingenuity to build quickly, within budget.

KAISER ENGINEERS

Division of Henry J. Kaiser Company
Oakland 12, California
Pittsburgh, Washington, D. C., Chicago, New York

• KE projects include work in Ghana, Japan, Puerto Rico, Vietnam, as well as the United States. They encompass such diverse assignments as nuclear fuel analysis, a nuclear research center, plutonium production reactor, steam-electric power station and a hydro-electric plant.

5458-P



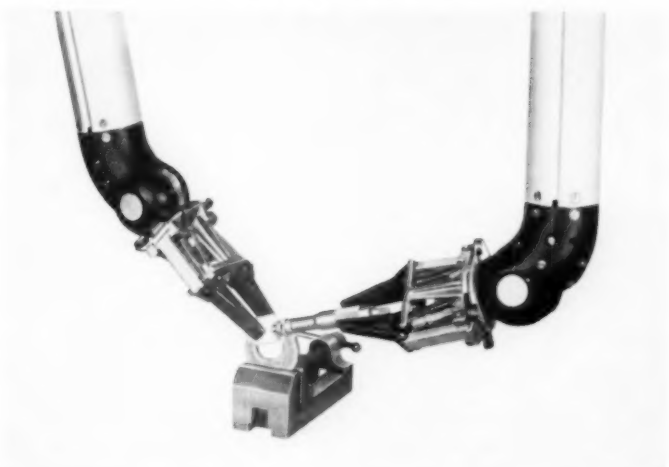
CRL manipulators...

AS OBEDIENT AS YOUR HAND!

Slave ends of CRL Manipulators obey perfectly—duplicate the natural motions of the operators' hands—make operation of the system amazingly simple. An operator becomes perfectly adept with practically no training.

Simplicity of operation is only one of several reasons research and production organizations all over the world specify CRL Manipulators. The system is versatile. Accessories such as special-purpose tongs, load hooks, motion locks, and protective booting allow adaption to a great variety of purposes. A continuous program of improvement . . . uncompromising workmanship . . . and standardized, interchangeable parts provide more reasons why you should consider CRL Manipulators for handling hazardous materials.

Central Research Laboratories will be glad to advise you on the handling of radioactive materials, explosives, hazardous chemicals, biological materials—in the layout of hot cells—in other research areas, too. For complete information, write CRL today.



Central Research Manipulators from basic Argonne National Laboratory design

Central Research laboratories, inc.

Red Wing, Minnesota, Dept. 101

This is a space ship floor maker

Sometime within the next several years, the first American will soar into orbit around the earth. He will be sealed in a small, cone-shaped space capsule mounted atop an Atlas missile. The missile will climb 100 miles in less than six minutes, where the capsule will disengage and go into orbit. The man will be alone in space.

The vehicle for this historic voyage is already in production, under the auspices of the National Aeronautics and Space Administration's "Project Mercury." One of the possible methods of heat protection is a beryllium heat sink, forged on two giant steel dies. Both dies are USS Quality Steel Forgings. The top die (shown being rough-machined on one of our vertical boring mills) will be convex, 20 inches thick and will weigh 26,520 pounds. The bottom die, concave and 18 inches thick, weighs 27,700 pounds. Both are 92 inches in diameter.

The heat sink of the space capsule will also be its leading face when re-entering the atmosphere. It will be traveling 18,000 miles per hour, subject to thousands of degrees of temperature and many times the force of gravity. Naturally, it has to have superb strength and heat-resistant characteristics. By the same token, the dies that shaped the capsule floor had to be perfect.

After forging, both dies were subjected to preliminary heat treating and preliminary machining. Then came quenching and tempering. A battery of tests followed: ultrasonic inspection, tangential tensile tests, Charpy V notch impact tests, grain size tests, bend tests and magnetic particle inspection. Only then were the dies ready to take the incredible forging pressure, exerted by the giant hydraulic closed-die forging press where the beryllium disc was formed.

We invite your inquiries or requests for our free 32-page booklet on USS Quality Forgings. Just write United States Steel, 525 William Penn Place, Pittsburgh 30, Pa.

USS is a registered trademark

United States Steel Corporation—Pittsburgh
Columbia-Geneva Steel—San Francisco
Tennessee Coal & Iron—Fairfield, Alabama
United States Steel Export Company

United States Steel

USS

SIGNIFICANT ADVANCES IN BERYLLIUM TECHNOLOGY COME FIRST FROM BRUSH

BRUSH SHOWS THE WAY TO

FUSION WELD BERYLLIUM

THE ATOM AGE METAL

Beryllium's low neutron-capture cross section and high neutron-scattering cross section make it an extremely valuable nuclear material. The lack of entirely suitable methods of joining has, however, limited its use in some areas of potential application.

Now Brush engineers can show you the way to fusion weld the metal. Non-porous and crack-free beryllium weldments, with properties superior to the base metal at elevated temperatures, have been achieved. At this stage, virtually all of this welding has been done on a laboratory basis. When present development work is completed, we feel we'll be ready to try, or to help you try, fusion welding of this atom age metal under production conditions.

The development of fusion welding, mechanical fastening, brazing, soldering, and other joining methods greatly broaden application horizons for beryllium.

Can this metal, its oxide, its alloys or our expanding experience with these versatile materials solve a problem for you? Let us try. Contact us at 5209 Euclid Avenue or ENdicott 1-5400 in Cleveland, Ohio.

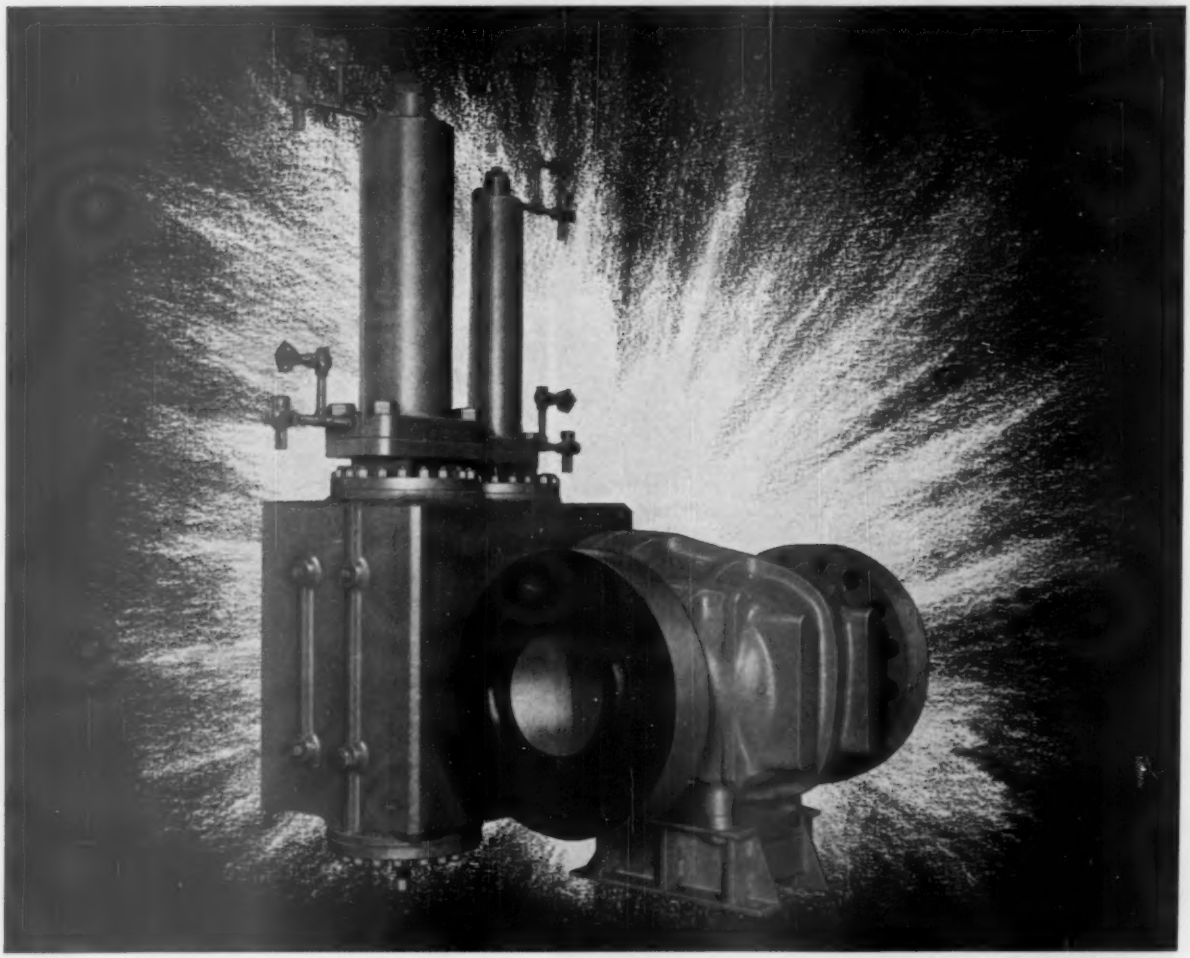
X-ray of a one-quarter inch thick beryllium weldment.

THE BRUSH BERYLLIUM COMPANY

Visit our exhibit at the Atomic Exposition, Booths 204-6, New York Coliseum, April 4–7.

ALLIS-CHALMERS

A-1230



Rotovalve unit for 2700-psi, 1050 F service.

A must for nuclear reactor service . . . valves that

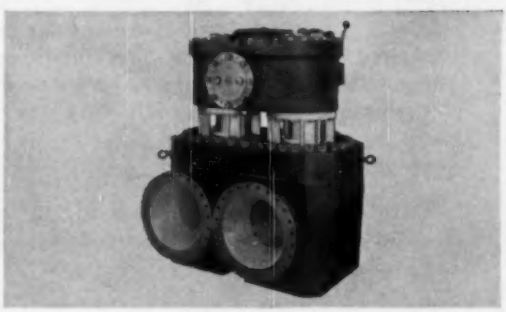
seat tighter with use

***Rotovalve* units accurately control or shut off** in high-temperature, high-pressure reactor applications. Units feature lantern ring with double packing, pressurized with the line fluid or purged to a bleed tank at lantern ring.

One example of current manufacturing is a 10-inch *Rotovalve* unit for operation at 2500 psi, 2500 F. Also being engineered is a 12-inch size for service at 4000 psi, 4000 F. Still another type combines a pair of valves within a single housing for use on dual, concentric pipes. Inner pipe carries 1400 F CO_2 to reactor; outer, 700 F CO_2 away from reactor.

Your Allis-Chalmers representative can arrange reactor valving engineered to your specific requirements. He also supplies a complete line of butterfly valves, including models for air-lock valving. *Contact him for detailed information, or write* ***Allis-Chalmers,*** *Milwaukee 1, Wisconsin.*

Rotovalve is an Allis-Chalmers trademark.



Duplex Rotovalve unit features a single operator — controls 1200-psi, 600 F steam, or 1500-psi, 300 F air. Operator allows both valves to open simultaneously, or one to open while the other closes. Saves space vital where entire reactor unit must be enclosed in radiation-proof structure.

FEWER MOLECULES MEAN STRONGER WELDS

When this 40-foot vacuum chamber (above) is evacuated to .03 microns, a single molecule can travel 15 feet without striking another molecule.

Many of today's "space" metals have an affinity for contaminants at high temperature . . . making welding an extremely critical operation. The Budd Company —pioneer in welding techniques—has solved many of the problems of making reliable welds in such metals as zirconium, hafnium, beryllium, columbium, tantalum and molybdenum.

Parts to be welded are placed in a vacuum chamber. The chamber is pumped down to .03 microns, to rid the box of contaminants; then is immediately refilled with inert gas to atmospheric pressure. Net result: stronger, high quality welds —impossible with conventional methods.

We are prepared to fabricate these materials today. Why not let us know how we can work with you? SpaceAtomics Division, The Budd Company, Philadelphia 32, Pa.

SPACEATOMICS Budd DIVISION

CRITICAL PIPING FOR THE NUCLEAR AGE

A HOT TEST LOOP OF 10″ INCONEL

PIPED BY MIDWEST

for Knolls Atomic Power Laboratory

Through this project . . . an important "first" in atomic power development . . . Midwest proved conclusively that heavywall Inconel piping can be fabricated and erected to meet the most stringent requirements.

Designed for testing materials and components of pressurized water reactors, this loop was fabricated by Midwest's St. Louis plant from Midwest-manufactured Inconel pipe and fittings, 10¾″ O. D. with a wall thickness of 1″. Other Inconel and stainless welding fittings and pipe, Inconel socket welding fittings and Inconel butterfly valves were also manufactured by Midwest.

Erection of the time- and money-saving prefabricated Inconel piping—all auxiliary piping, the complete electrical power and control system and instruments—was handled entirely by Midwest's competent field erection department.

For complete service . . . welding fittings, shop fabricated piping, and erection service . . . CONTACT MIDWEST.

Write for NEW 20-page bulletin—CRITICAL PIPING FOR THE NUCLEAR AGE—describing Midwest's nuclear experience.

MIDWEST

MIDWEST PIPING COMPANY, INC.

1450 South Second Street, St. Louis, Mo.

6945

NO STRANGER

. . . to the atomic field, A. O. Smith's supplier-status goes all the way back to the Manhattan project. Our specialized skills and facilities have been called on consistently for fabrication of reactor vessels, reactor internals, pressure vessels, heat exchangers, steam generators, pressurizers, feed water heaters. We invite you to write for facts about A. O. Smith's experience and creative productivity as they might be adapted to your particular area of nuclear development.

Pressurized water reactor vessel designed by A. O. Smith.

BOTH SOLID WALL AND EXCLUSIVE MULTI-LAYER CONSTRUCTION . . .

available at A. O. Smith. Adaptable to many atom-era fabricating needs, the unique Multi-Layer concept features successive layers of relatively thin steel plate wrapped and seam-welded. Vessel walls can be built to any desired thickness with maximum safety.

Through research . . . a better way

A.O.Smith

CORPORATION

ATOMIC EQUIPMENT SECTION

MILWAUKEE 1, WISCONSIN

A. O. Smith INTERNATIONAL S.A., Milwaukee 1, Wis., U.S.A.

swagelok GOOP®

prevents galling
prevents seizing
protects valuable equipment

GOOP is the amazing new compound for ending the costly galling, seizing and resultant destruction of threaded parts.

The line includes three separate products: Blue GOOP, Silver GOOP and High Purity GOOP.

Silver Goop® is formulated to prevent seizing and galling of threaded parts, regardless of applied load, at temperatures up to 2100° F. It reduces take-up torque on threaded parts. Will not drip off red-hot surfaces nor give off poisonous metal or oxide fumes at high temperatures. Resists water washout.

Blue Goop® is an anti-seize and sealing compound for use on titanium, stainless steel, steel, aluminum and high temperature alloys. Withstands temperatures up to 400° F. Impervious to water washout, most acids and all petroleum solvents.

High Purity Goop® is an anti-seize and sealing compound for titanium, stainless steel, steel, aluminum and high temperature alloys. Withstands temperatures up to 400° F. Impervious to moisture, high voltage and cyclic thermal stress. Recommended for use wherever prevention of product contamination is an important factor.

CRAWFORD FITTING COMPANY

8884 East 140th Street

Cleveland 10, Ohio

Crawford Fittings (Canada) Ltd., Niagara Falls, Ontario, Canada

"Higher Education . . . Our Greatest Tool"

OSCAR G. MAYER
Chairman, Oscar Mayer & Co.

"During the last twenty years we have had dramatic evidence of what massive research can accomplish. Every thinking American today is acutely aware that our future welfare depends upon this vital activity.

"But sound higher education is the prerequisite of good research; it is vitally important that our higher education be constantly improved, beginning with our secondary schools. Higher education is the only means with which we can mine our most valuable natural resource: the creativity of the human mind in all fields, social and cultural as well as scientific.

"By supporting the college of your choice in its efforts to provide the best possible faculty and physical facilities, you are investing in the one tool with which to shape favorably the future of America."

If you want more information on the problems faced by higher education, write to: Council for Financial Aid to Education, Inc., 6 E. 45th Street, New York 17, N. Y.

Sponsored as a public service, in cooperation with the Council for Financial Aid to Education

HIGHER EDUCATION
KEEP IT BRIGHT

ADVERTISING COUNCIL
PUBLIC SERVICE

CHARCO
DRY BOX GLOVES

PROVIDE DEPENDABLE PROTECTION IN CRITICAL OPERATIONS AT

ARGONNE NATIONAL LABORATORY

(Photo by courtesy of Argonne National Laboratory)

CHARCO "NEO-SOL" DRY BOX GLOVES IN USE AT ARGONNE'S PLUTONIUM REACTOR FUEL ELEMENT FABRICATION FACILITY.

PROUD RECORDS OF RELIABLE PERFORMANCE BY CHARCO DRY BOX GLOVES HAVE BEEN MADE IN THIS COUNTRY AND ABROAD, IN MAJOR ATOMIC ENERGY INSTALLATIONS: ALSO IN BIOLOGICAL AND INDUSTRIAL RESEARCH FIELDS!

CHARCO DRY BOX GLOVES

FLEXIBLE, FINGER SENSITIVE AND COMFORTABLE

Both CHARCO Dry Box Gloves are manufactured of MILLED NEOPRENE, by the Multiple Dip Cement Method, in which MOLECULAR SOLVENT solutions of Neoprene are used, to meet demands and rigid specifications required for nuclear and biological work. — The Latex Coagulation Process is NOT used in manufacture of CHARCO Dry Box Gloves!

"NEO-SOL"®

PREMIUM QUALITY, ALL MILLED NEOPRENE. THESE GLOVES ARE OIL, CHEMICAL AND OZONE RESISTANT. THEY CONFORM TO REQUIREMENTS OF ARGONNE NATIONAL LABORATORY SPECIFICATIONS PF-1-b-(Rev. 6).

"RAD-BAR"®

SEAMLESS, LEAD-LOADED, MILLED NEOPRENE ARE OF A DENSITY OF 3.95 GRAMS PER CUBIC CENTIMETER. UNDER ACTUAL TESTS THESE GLOVES HAVE BEEN PROVEN TO SHIELD OUT SOFT GAMMA RAYS MORE THAN 80%.

"NEO-SOL" and "RAD-BAR" gloves offered in a complete range of styles and thicknesses, to fit 5, 7 and 8 inch diameter ports. The "RAD- BAR" glove is also offered in standard short lengths.

EACH CHARCO DRY BOX GLOVE IS HIGH VOLTAGE TESTED, AND SO CERTIFIED!

A severe high voltage electrical test is applied to each glove, after visual and all other tests are completed, to insure freedom from hazardous defects which might escape detection by other methods of testing and inspection.

INSTALL CHARCO DRY BOX GLOVES AND YOU WILL INCREASE BOTH EFFICIENCY AND PROTECTION

Our Research and Testing Laboratories Will Welcome The Opportunity To Help Solve Your Problems.

WRITE FOR BROCHURE AND TECHNICAL DATA

CHARLESTON RUBBER COMPANY

7 STARK INDUSTRIAL PARK - CHARLESTON, SOUTH CAROLINA

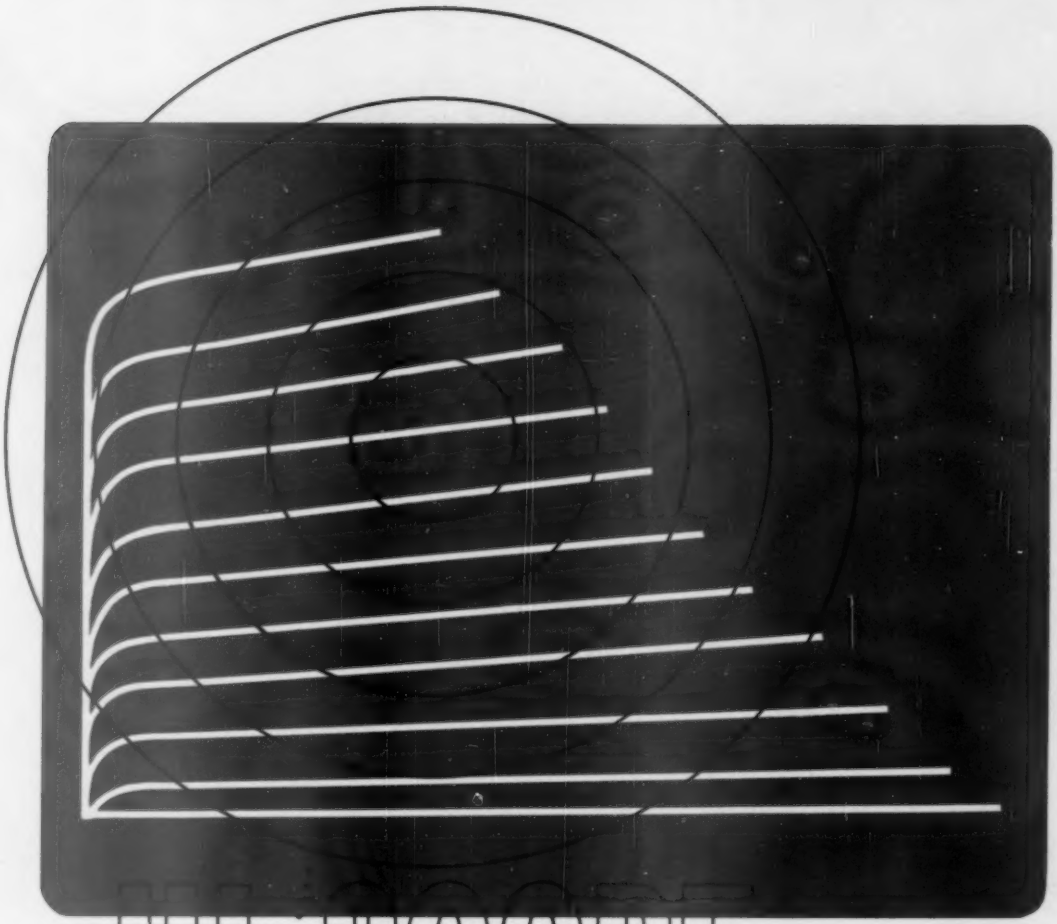
experience (eks pē'ri ens) n. Skill or wisdom gained by actually doing things. Knowledge gained by trial and practice. v.t. To undergo; to know or learn through one's own actions.

Doing is experience. Vitro has already designed two billion dollars worth of nuclear facilities ..whose usefulness has been expanded by the early application of new engineering techniques. This experience assures you an on-time facility — and profitable design which remains competitive for years to come. Find out today how this background can be put to work for you.

engineering the future

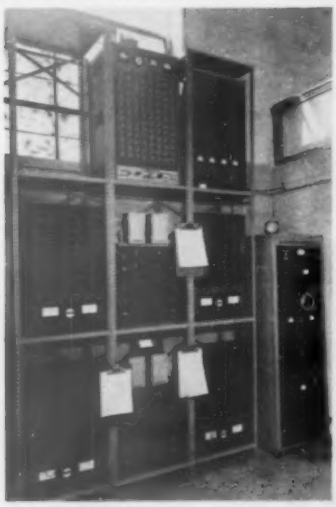
Vitro ENGINEERING COMPANY

225 PARK AVENUE SOUTH, NEW YORK 3, N. Y. • A DIVISION OF VITRO CORPORATION OF AMERICA



HI/SCOPE

General Transistor's Program of Service Especially Helpful in Designing For Military Use



General Transistor offers you a program of assistance that is truly unique in scope. This service, which we call HI/SCOPE, reflects the flexibility of our company. It can be personalized to anyone's requirements, and is especially helpful in designing for the military.

Here are some of the ways we are currently helping GT customers...ways in which we'd like to help you.

100% Lot Preconditioning

Let's assume you have equipment which must undergo severe environmental conditions... be subjected to high mechanical shock and vibration. To be certain that all the transistors you intend to use will withstand this type of exposure, we will set up a preconditioning program that will test out every single unit before we ship to you.

GENERAL TRANSISTOR CORP.

91-27 138th Place / Jamaica 35, New York

Special Electrical Parameter Testing

Certain transistor applications are so unusual that they cannot be completely described by standard parameters. If you are in such a position, we will design a test fixture to closely approximate actual circuit performance. This procedure will provide assurance that 100% of the transistors delivered to you will perform satisfactorily.

Special Selection on Standard Catalog Types

In many instances you may find that a standard catalog transistor is about 90% acceptable, but still needs improvement in a few parameters. In such a case, please ask us about the possibility of getting these improvements. We can tell you what increase in specifications is feasible, and produce the units to this spec. Thus, you get the desired parameters without having to redesign or wait for a custom-built semiconductor.

Special Reliability Testing Programs

Must your completed systems meet a high reliability requirement? If so, you may wish special procedures to be established with regard to your reliability programs. This is another GT service. When necessary, we will build such transistors on a specially designed production line, check them exhaustively to hold tight parameter tolerances, and subject large lots to specific and unique life tests. In many cases, we have established a program so that we ship those units which have high survival probability in your application. These things we have done, and will do again, at your request. Sound helpful?

Qualification Approvals

Let's consider the case where you want to design a certain transistor into a system for the government, yet a government specification does not exist for the transistor. You must be ready to substantiate your use of the non-standard part. Here's what GT can do to help your case. We will run a qualification approval procedure in the same format we would for a military type. Then we'll provide you with this necessary data. This will greatly accelerate your approval for use of this transistor type.

High and Low Temperature Testing

Standard transistor parameters are generally controlled at room temperature. Yet many systems must function at other ambients. If you have a problem specifying electrical parameters at room temperature in a manner that will be valid at high or low temperatures, we are ready to assist. General Transistor is prepared to run any measurements you dictate, at any specified ambient. We can do this on complete production lots if you feel it essential.

Special Coatings or Encapsulations

In your manufacturing process, do you expose transistors to any kinds of solvents or potting materials? If so, just let us know. By using special highly resistant coatings, we'll make sure that the transistor case and markings are not vulnerable to solvent attacks.

Cost Economies Through Parameter Modifications

Yield has a strong influence on transistor cost. To give you the best economies and at the same time give you the most desirable quality, we offer this working arrangement. At your request, General Transistor will suggest slight modifications of your specifications which will allow us to ship the major portion of a production run. We will make the necessary measurements and indicate what the various parameters should be and what proportions of the run will fall into preselected types. If you then design your system to use this production mix, you will benefit from some genuine economies.

Samples with Parameter Measurements

Assume you want to check out the margins in a design. You require upper and lower limit samples of a certain transistor type. We'll be happy to supply you with sufficient samples to cover the spread in one or two significant parameters. Thus, you can experimentally determine the performance of your circuit.

Circuit Design

If you are starting on a new program, you may want some information on what performance you can expect from state-of-the-art circuits. We will provide you with such typical circuits at your request, together with data on the performance of our transistor types within these circuits.

Special Production Runs

Assume that your transistor application is so unusual that units are not available from standard production. What can be done? We will analyze your requirements and decide whether it would be feasible to make a special production run of transistors to meet your needs.

These services are typical of GT HI/SCOPE.

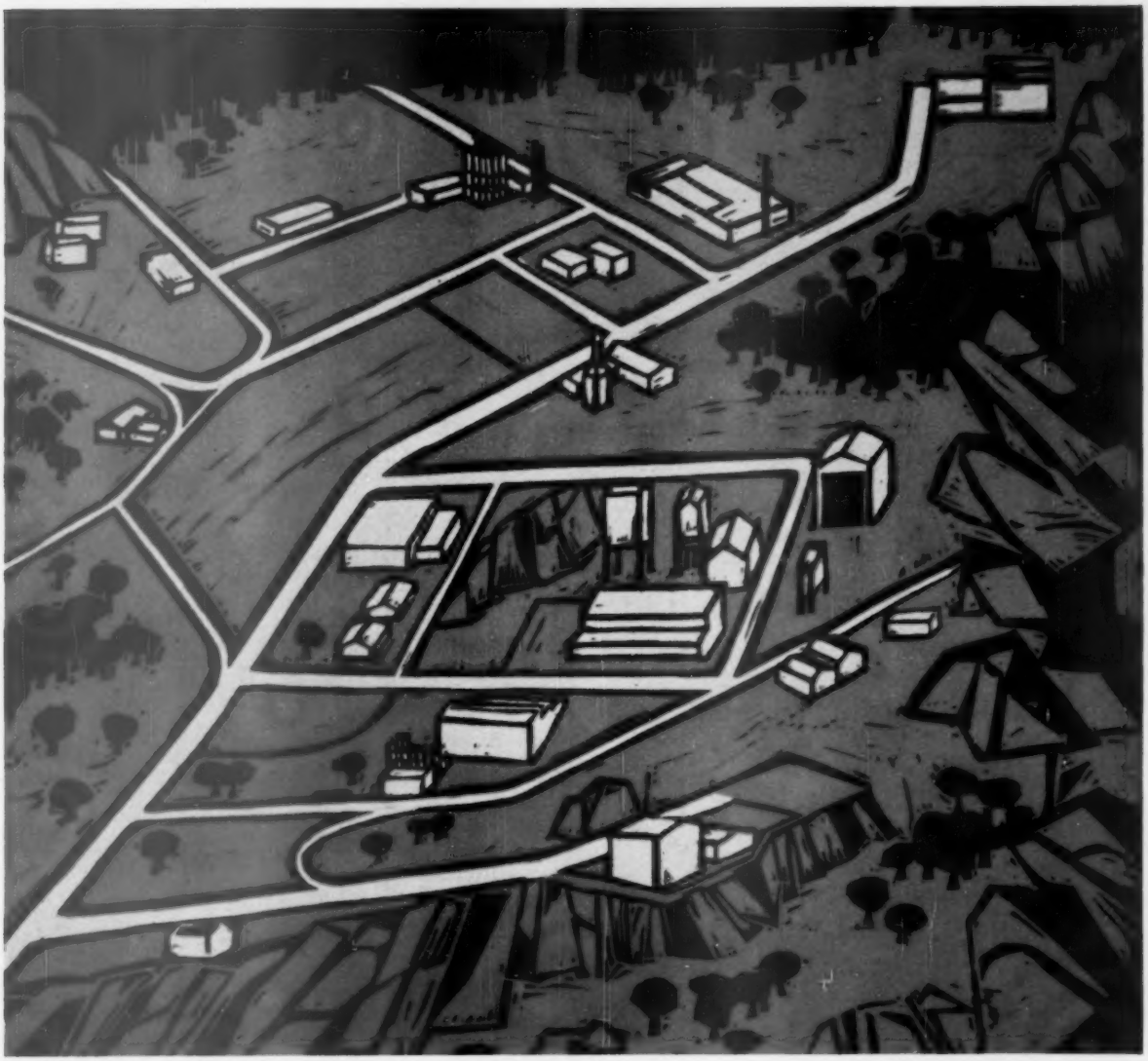
Write or call for specifics

relating to your own projects.

GENERAL TRANSISTOR CORP.

91-27 138th Place / Jamaica 35, New York

1063/360/65



AI's extensive field laboratory is located in California's Santa Susana Mountains. *Woodcut by Edward Kysar.*

How can A.I. facilities help you plan a Nuclear Program?

In the picturesque Santa Susana mountains near Los Angeles, Atomics International has built an extensive field laboratory for research, engineering and testing in the nuclear sciences. Here, and at a headquarters complex in the valley below, men who pioneered the creative uses of atomic energy are applying their experience to develop advanced nuclear reactors and associated equipment.

Fourteen years of experience in developing various types of reactors for the Atomic Energy Commission and other organizations have given the men of Atomics International a collective background unparalleled in the industry. The facilities at their disposal are among the most sophisticated and extensive in the world.

Results of AI's work have been demonstrated in projects for the AEC which include the Organic Moderated Reactor Experiment at the National Reactor Testing Station in Idaho and the Sodium Reactor Experiment at the company's field laboratory. Additionally, AI built and is operating SNAP II, a 220 pound prototype reactor to produce three kilowatts of electricity for space vehicles.

Atomics International is also building large power reactors for electric utilities in Ohio and Nebraska under AEC programs. Studies are underway for other power reactors in the United States and Europe. Research reactors have been built by AI for Denmark, Germany, Italy, Japan, Puerto Rico and several sites in the United States.

For details contact: ATOMICS INTERNATIONAL, Canoga Park, California, U.S.A. Cable address: ATOMICS.

ATOMICS INTERNATIONAL
A DIVISION OF NORTH AMERICAN AVIATION, INC.
PIONEERS IN THE CREATIVE USE OF THE ATOM

Other offices in: Washington, D.C., U.S.A.; Geneva, Switzerland. Affiliated with: INTERATOM, Bensberg/Cologne, Federal Republic of Germany and DYNATOM, Paris, France.

You are
welcome
to visit with
our Editors and
Representatives
at the
NEW YORK
COLISEVM
during the 1960
Atomic Exposition

We're at Booth 312

NUCLEONICS / A McGraw-Hill Publication

Many executives think of the "nuclear market" strictly in terms of *potential.* Nucleonics Magazine is using simple facts to correct this impression.

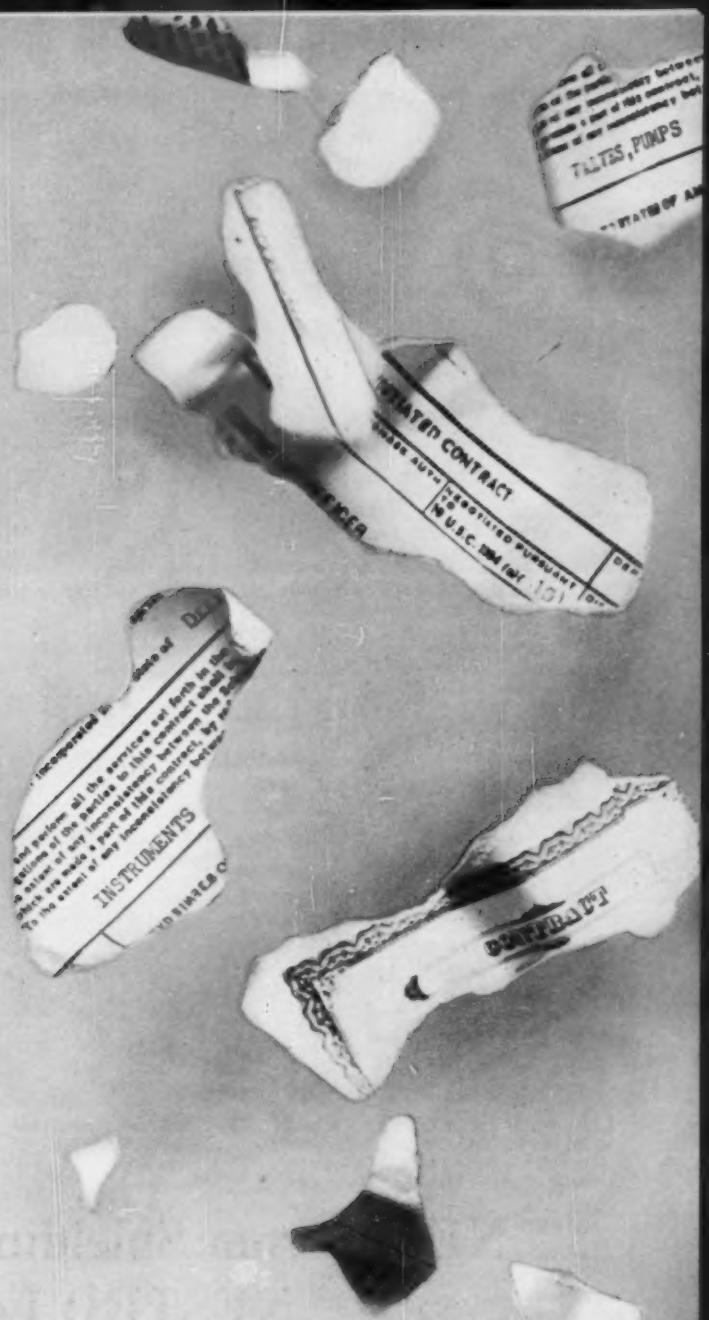
The advertisement opposite appears in Business Week magazine and pinpoints the practical, realistic opportunities that the nuclear market holds for men with the courage, imagination and skill to benefit from them.

Some readers of the Business Week advertisement may well be coming your way before long as customers, suppliers, sources of finance—even as competitors.

As spokesmen for the industry for 12 years, Nucleonics makes the strongest impression on our fast growing industry both here and abroad.

NUCLEONICS

A McGRAW-HILL PUBLICATION
330 West 42nd Street, New York 36, New York



DID YOU GET A PIECE OF THIS $45,000,000 CONTRACT?

Right now, the last of *this* money (all private funds) is being spent so that the now famous Dresden Nuclear Power Station (whose prime contractor was General Electric Company) can begin producing electric power for the Commonwealth Edison Company, serving the Chicago area, by mid-1960.

What can this mean to *you*? If you've been thinking of the nuclear market as something "off in the future", here are facts about The Dresden Station you should know about.

More than 150 companies that make everything from delicate instruments to building blocks—many of them *small* companies—have sold their knowledge, ideas, products and services to help create The Dresden Station. The managements of these companies *know* that the nuclear market is spending money, big money, *right now.*

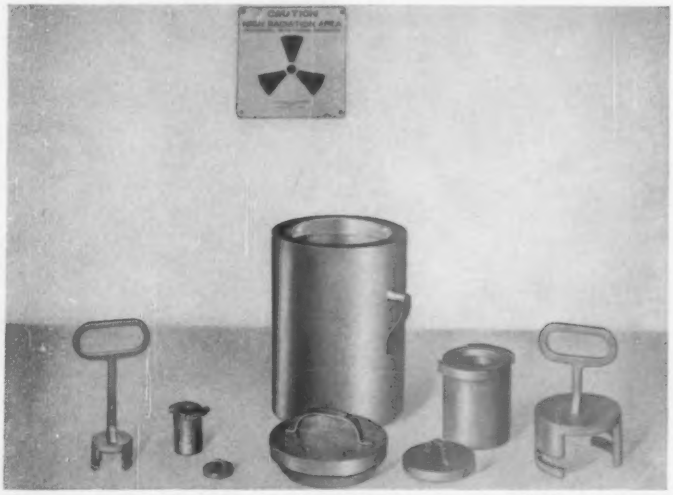
Here's another fact for your consideration. Right now, approximately 1900 different companies sell and advertise to the nuclear market. Construction companies. Chemical companies. Metal fabrication companies. Designers. They know that the time to start developing this market is *now.*

If you have felt that this amazingly dynamic market is "not for you right now"—may we send you a complete article on The Dresden Station together with a list of the suppliers? Only 75¢. Read it *looking* for opportunity, as so many others have.

Take a look at Nucleonics Magazine, too! This authoritative market-place for nucleonic ideas, products and services reaches key buyers all over the world. Use it to establish your own "stake" in this fast growing field.

NUCLEONICS ... *the voice of the nuclear age*

A McGRAW-HILL PUBLICATION · 330 West 42nd Street, New York 36, N. Y.



The set consists of three containers, their covers, and lifting hooks to engage the two small casks.

Technician inserting hot material in middle-size container.

Illustrating use of lifting hook provided for handling small containers.

The completely nested set, with lifting hooks. A special locking device for the large container is available.

NEW...from Shielding Headquarters... NESTED Lead Casks

Skillfully engineered, precision made, this set of nested containers is designed to meet a need for safe, handy, space-saving storage of hot materials.

The small can carries one-half inch lead protection around a 3/4" x 2-1/8" cavity; the medium can has one inch of lead around a 2-5/16" x 5" cavity; the large container has a two inch lead thickness around a 5-7/16" x 8-1/2" cavity. All containers have lead lids. Lifting hooks for handling the insert containers come with each set. A locking device for lid of large container is optional.

This cask set is the newest item in a wide range of shieldments produced by National Lead for reactor, hot lab, hospital and industrial applications. All bear the unmistakable mark of quality of the leader in lead—benefiting by a background of nuclear field activities unmatched in the shielding industry.

Write the Branch nearest you for prices on these new nested casks.

National Lead Shielding

NATIONAL LEAD COMPANY · General Offices: 111 Broadway, New York 6, New York. Branches in Atlanta; Baltimore; Boston; Chicago; Cincinnati; Cleveland; Dallas; Depew (N. Y.); Detroit; Kansas City; Milwaukee; New Orleans; Omaha; Perth Amboy, (N.J.); Pittsburgh; St. Louis; St. Paul. Pacific Coast: Morris P. Kirk & Son, Inc., Los Angeles, Emeryville (Calif.), Phoenix, Portland, Salt Lake City, Seattle. Canada: Canada Metal Co., Ltd., Montreal, Toronto, Vancouver, Winnipeg.

NUCLEONICS

JEROME D. LUNTZ, *Editor and Publisher*

APRIL, 1960

The 10-Year Program

THE BLUEPRINT for achieving economic atomic power delivered by the Atomic Energy Commission to Congress in February is an exciting one (see pgs. 71–82, this issue). Although the approach used by AEC was a careful, conservative one, the pattern that emerged was full of confidence on the early achievement of the goal.

In fact, despite AEC's discussion in its basic statement of getting economic power in *10* years, the likelihood was indicated at the hearings that this would happen much sooner, possibly in *5* years.

THE AEC presentation was made in an atmosphere of cordiality and harmony between AEC and the Joint Committee on Atomic Energy, the first such harmony that has surrounded the controversial atomic power program in years. In the past, AEC came into its annual presentation on the defensive, trying to fight off what it felt were unreasonable pressures to move the program this way or that way. And so its proposals always seemed to be ones that were answering one or another argument.

But this year, all was different. AEC finally grabbed hold and outlined a clearcut, well-defined program that no JCAE member took issue with in any large way. The reaction of JCAE was as if to say: "We know that you've given the whole thing very thorough consideration and have brought to bear on the problem the best brains in the country. We accept your thinking."

Undoubtedly, the amicable mood of the JCAE was also encouraged by the fact that: (1) atomic power is not a good political issue in 1960; (2) the edge has been taken off the competition with the U. K. and the U. S. S. R. by the slowing down in their efforts; and (3) the need to push hard to help other countries has been reduced by their improved energy situation.

Now, the big incentive for the U. S. in its program is to achieve economic atomic power for its own value domestically and as part of the larger U. S. effort to stay in the forefront of important areas of technology.

THE PROGRAM to do this is in fact a modest one. If we had any criticism of the program, it would be that it is too modest in scope and depth. But the program is a basic one, one that provides a foundation for building on it as the effort moves ahead.

AEC chairman McCone emphasized this when he said:

> " . . . plants which we envisage as essential building blocks in the program are *not*, by any means, all of the plants which will be built in the U. S. during the next ten years. It is our opinion that as each successive step in our program shows the possibilities of lower cost plants and cheaper power, publicly and privately owned utilities will themselves build plants, with or without government aid, in order to meet the evergrowing demand for electric power. Many of these plants will be built for the sole purpose of meeting power demand and will not be developmental units as such."

McCone explained his optimism as follows:

> "My conclusion as to this possibility is prompted by the dramatic developments in diminishing capital costs and lowering power costs of two of the most advanced reactor concepts, the pressurized and the boiling water designs. You are familiar with the fact that the General Electric Company has offered a 300 megawatt electrical, boiling water plant to the utility industry at a capital cost of about $200 per kilowatt, and a guaranteed fuel life of about 14,700 megawatt days per ton. The Westinghouse Company has offered a pressurized water plant on about the same basis. These figures are significantly lower than the costs of the several plants now under construction or nearing completion which are based on the technology of 1955 to 1957; moreover, these figures are substantially lower than the figures developed through studies authorized by this Committee two years ago and presented to this Committee last spring . . . I am gratified to be able to inform you that executives of utility companies have reported to me that for the first time in the long and sometimes discouraging history of nuclear power development they can consider the construction of these large plants on purely an economic basis, in competition with conventional plants in areas of the United States where fuel is particularly expensive."

Here then is a blueprint for bringing atomic power on the line competitively in this decade of the '60's, possibly by the mid-'60's.

Irradiation Reactions in Hydrocarbon Gases

Secrets of radiation-induced ion-molecule and free-radical reactions come to light as 2-Mev electrons bombard methane, neopentane, ethylene and mixtures of ethylene with argon and propane

By FREDERICK W. LAMPE, *Humble Oil and Refining Co., Baytown, Texas*

PETROLEUM CHEMISTS are eagerly pursuing the radiation chemistry of hydrocarbons. Our approach at Humble is to irradiate gaseous hydrocarbons and measure the *G*-values (molecules formed per 100 ev absorbed) of products that are formed (and negative *G*-values for gases that disappear). Quantitative comparisons among yields at different pressures, temperatures and concentrations enable us to find out which molecular species take part in the reactions, which reactions are ionic and which reactions are free-radical in nature. We also use mass-spectrometer evidence in combination with our radiation data.

High-energy particles passing through a chemical system produce both ions and free radicals. The chemical reactions of free radicals with molecules and with each other have been understood for some time; information concerning them is available in the literature from experiments in which ions are not present. Considerably newer is the study of ion-molecule reactions. It was thought for many years that ions formed in the primary process merely underwent neutralization, thus making excited species and more free radicals. In recent years, however, mass-spectrometric investigations have uncovered many extremely rapid reactions between ions and molecules in the gas phase. These reactions occur so rapidly that they appear capable of competing favorably with neutralization reactions previously thought to destroy the ions. Thus such reactions are important whenever ions are formed —as in radiation chemistry. We can investigate the gas-phase reactions between ions and molecules in the mass spectrometer; so we have chosen the radiation-chemistry study of gaseous hydrocarbons as our first area of study.

Why We Irradiate; What We Can Find

Radiation chemistry of hydrocarbons is not a new field of study; the first investigations were by S. C. Lind and his collaborators in this country and Mund and coworkers in Europe over 30 years ago (*1*). In recent years, however, new intense and convenient sources of ionizing radiation have given new impetus to radiation chemistry. Most interesting to a petroleum company is the radiation chemistry of hydrocarbons. Since it appears that exploitation of radiation processing will be considerably dependent on properties unique to it, a thorough understanding of the basic processes of radiation chemistry is essential. We must learn more about ionizing radiation, what it does and what it can do before we can hope to put it to use.

In the area of hydrocarbon chemistry, we must ask ourselves several questions: Can high-energy radiation make active transient species of hydrocarbons, whose reactions with normal molecules might make possible otherwise difficult or hitherto unknown conversions of hydrocarbons? If so, what are the species and what is the nature of their reactions with hydrocarbon molecules? How long will they exist under given conditions? How can one affect their lifetimes?

These are important questions with bearing on the possibilities of ultimate commercial importance of radiation chemistry. We must answer them.

High-energy radiation may produce the already familiar entities, carbonium ions (R_3^+) and free radicals, in environments free of catalyst fragments, photosensitizers, high temperature, etc. This might make possible modifications and improvements in processes that depend on their reactions. Even more important, however, is the possibility that high-energy radiation may afford a unique method of forming different, active intermediates that undergo new types of reactions with hydrocarbon molecules. This would open a whole new field of hydrocarbon conversion.

Mode of Study

Our program consists of irradiation of gaseous hydrocarbon systems with 2-Mev electrons followed by observation of chemical changes produced under various temperatures, pressures and radiation intensities. Chemical changes occur in the presence of both ions and free radicals. At the same time we investigate, in so far as possible, comparable systems in the mass spectrometer with which we observe only the consequences of ionic reactions. By application of our informa-

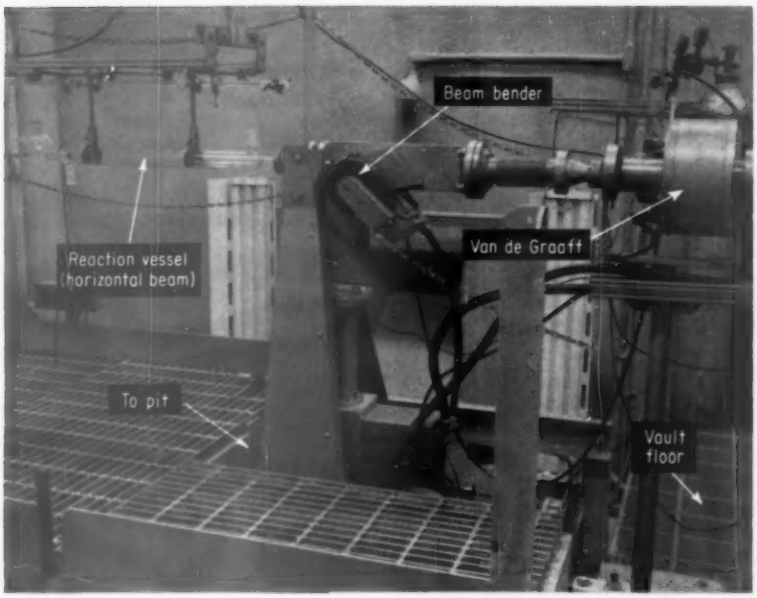


FIG. 1. GAS-IRRADIATION APPARATUS uses beam of 2-Mev Van de Graaff either directed horizontally at reaction vessel at left or bent down to heavier vessels

tion on ionic and free-radical reactions to the experimental results of irradiated systems, we attempt to elucidate the reaction mechanisms. Our experimental irradiation techniques have led us to some interesting results and conclusions regarding several hydrocarbon systems.

Experimental Techniques

Aside from necessary chemical analyses there are three distinct parts to a radiation-chemistry investigation: (1) a source of radiation, (2) reaction vessels to contain irradiated materials, (3) a method of determining the amount of energy absorbed by the reacting system.

Radiation source. We use electrons for the irradiations. Our source is a Type AK Model S 2-Mev Van de Graaff accelerator, mounted in a horizontal position as seen in Fig. 1. With this arrangement we use either the horizontal beam emerging from the 1-in. window or the vertical beam formed by bending through 90 deg. We use the horizontal beam for irradiations of gaseous systems at low pressures. For irradiations at high pressures the vertical beam is preferable. It can enter at the top of the reaction vessel, and this simplifies support of heavier reaction vessels and construction of entrance windows. The vertical beam emerges from a large scanning window 2 ft below the floor of the radiation vault (lower right, Fig. 1) and about 4 ft above the floor of the pit.

With the horizontal beam we are limited to a current of ~100 μa. Beam current can be increased to 250 μa with the large scanning window used with the vertical beam.

Reaction vessels. In general, vessels used in low-pressure irradiations are Pyrex cylinders ~1 in. in diameter and 24–32 in. in length (see vessel, Fig. 1). We jacket them to maintain constant temperatures other than room temperature. Entrance windows of all our Pyrex vessels are 1-mm-thick Pyrex flats fused onto the glass tubing. In the opposite end of the vessel there is a 3-mm-thick stainless-steel disk, slightly smaller in diameter than the inner cylinder walls, supported by a 1/16-in.-diameter tungsten wire. The tungsten wire in turn emerges from the glass vessel through a seal. The disk collects electrons and serves as a current monitor during irradiation. Heating of the Pyrex windows limits the incident beam to ~10 μa. Higher incident currents require aluminum or stainless-steel windows. Most of our gas-phase work, however, has been with low incident beam currents, and the all-glass vessels are quite satisfactory.

For high-pressure gas-phase irradiations a much heavier reaction vessel is required (Fig. 2). It is stainless steel throughout. The window consists of nineteen 1/4-in. holes drilled in a hexagonal pattern and covered on the under surface by a 13-mil stainless-

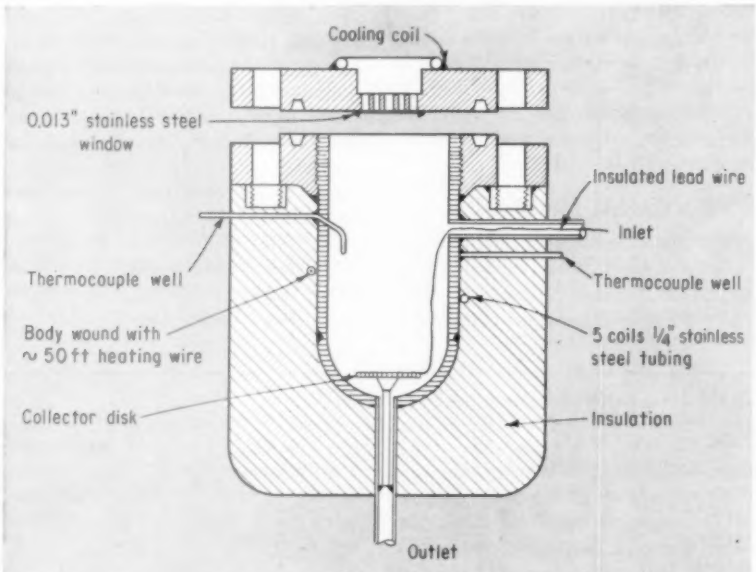


FIG. 2. HIGH-PRESSURE VESSEL has window made by drilling holes in heavy top and covering them with thin plate. Cooling coils, heating coils and thermocouple wells provide temperature control during irradiation. Collector disk monitors current

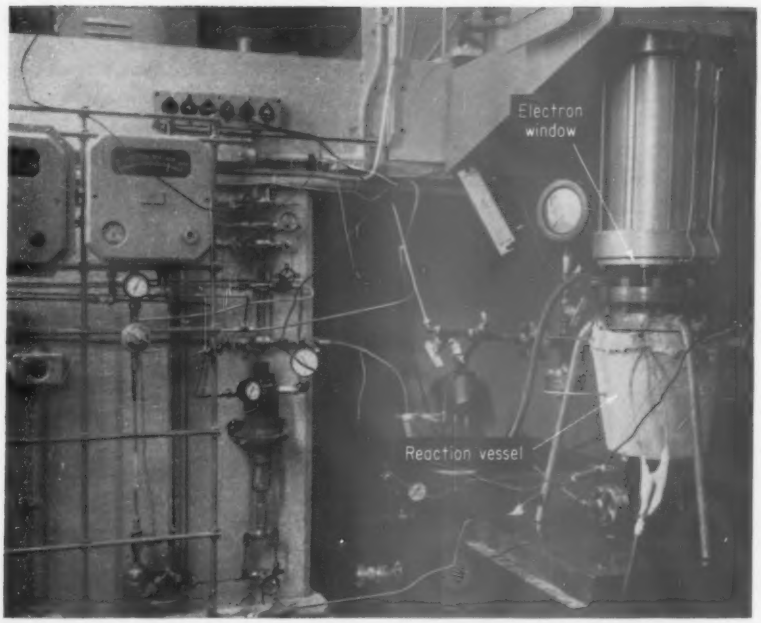


FIG. 3. LINES, GAGES, VALVES surround vessel of Fig. 2 in position for irradiation under vertical beam from Van de Graaff accelerator on floor above

steel plate. The plate is welded to the head of the vessel. A noninductively wound Nichrome element provides heat. The vessel, shown in position for an irradiation in Fig. 3, has been satisfactory for temperatures up to 480° C and pressures up to 700 psi. It can be used for either batch or flow experiments.

Dosimetry

Acetylene subjected to high-energy radiation polymerizes to make an amount of cuprene and benzene proportional to the amount of energy absorbed by the acetylene (*2–4*). Thus it is convenient to use acetylene as a dosimeter.

In our gas irradiations we have thin-target geometry; that is, the energy of a primary electron is essentially constant along the entire path in the gas. For this situation the basic equation for energy loss per centimeter of path by an electron traversing gas is $\Delta E/\Delta x = \alpha NZB$.

Here α is a constant that depends on electron velocity; thus for us it depends on window thickness and initial electron energy. We determine it for any particular setup by irradiating acetylene, measuring the amount of cuprene and benzene produced, using the established radiation yield (G-value) to determine the total energy loss and dividing by path length to find $\Delta E/\Delta x$. N is molecules/cm³; Z is electrons/molecule. B is stopping number for electrons, which can be calculated if the average ionization energy is known (*5*). In the calculation of B we assume the average ionization energy of hydrocarbons to be 11.5 ev. Although this may not be exactly correct, the $\Delta E/\Delta x$ values for hydrocarbons other than acetylene are in error only to the extent that average ionization energies of these hydrocarbons are different. With α and B known, the $\Delta E/\Delta X$ value for the irradiation system under investigation can be calculated.

EXPERIMENTAL FINDINGS

We have conducted high-energy electron irradiations of methane, neopentane (2,2-dimethyl propane), ethylene, ethylene-argon mixtures and ethylene-propane mixtures (see *Gas Dictionary*, page 65). For methane, neopentane and ethylene radiolyses it appears that reactions of ionic entities formed in the primary act are very important in the mechanism of the over-all chemical change.

Argon transfers energy (charge or excitation) to ethylene with little or no change in the course of reaction. Studies of propane-ethylene mixtures at high temperatures and pressures indicate a chain formation of pentane consistent with a free-radical mechanism.

Methane

Subjecting methane to ionizing radiation produces hydrogen, ethane, ethylene, propane, butane and perhaps pentanes as gaseous products (*1, 6, 7*). In addition, a nonvolatile substance of empirical formula C_nH_{2n} is formed. In all the irradiations there is little or no change in total pressure. Table 1 has G-values for electron, alpha-particle and deuteron irradiations of methane. Doses for alpha particles were computed from their ion-pair yields (*1*) by using 30.1 ev as the energy required to produce an ion pair in methane (*8*).

Methane G-values are independent of pressure, and the near-equalities of $G(CH_4)$ and $G(H_2)$ for electron and alpha-particle radiation (Table 1) are evidence that they are also independent of radiation intensity over a wide range. Also important is the relation among rates of formation of products. All products we observe are formed simultaneously; the large-molecular-weight compounds are formed directly, not as a result of the action of the radiation on products that have smaller molecular weights.

Ion-molecule reactions. Simultaneous product formation and pressure and intensity independence of the energy yields appear irreconcilable with a reaction that proceeds by free radicals only. To account for the observed

TABLE 1—G-values for Methane Irradiation

Compound	(*1.7-Mev electrons*) (*3*)	(*6-Mev α-particles*) (*1*)	(*12-Mev D^+*) (*2*)
CH_4	−7.6	−7.3	−8.3
H_2	5.7	5.5	
C_2H_6	2.1	1.1	
C_3H_8	0.14	0.38	
C_2H_4	0.05	—	
C_4H_{10}	0.04	0.22	

intensity and pressure independences we require one or more intermediate species that react in a single way so rapidly that no other reaction of that species can compete; to account for simultaneous product formation we require a similarly rapid reaction but in addition, one that involves formation of a carbon-carbon bond.

Recently observed reactions between ions and molecules in methane (*9–13*) appear to satisfy these requirements. Of the ions in the methane mass spectrum, 85% are CH_4^+ and CH_3^+, which react as follows:

$$CH_4^+ + CH_4 \rightarrow CH_5^+ + CH_3 \quad (1)$$
$$CH_3^+ + CH_4 \rightarrow C_2H_5^+ + H_2 \quad (2)$$

The rate constants of Reactions 1 and 2 are so large that the reactions must be considered extremely probable in irradiated methane. Reaction 2 accounts for simultaneous hydrocarbon buildup. Simultaneous buildup of higher hydrocarbons by this path is possible only if neutralization of CH_4^+ and CH_3^+ does not occur before Reactions 1 and 2. The results of Biondi and Brown (*14*), though not directly applicable to methane, suggest that neutralization would be slow relative to Reactions 1 and 2.

The observation that ~50% of the total hydrogen produced in radiolysis of methane comes from a non-free-radical reaction (*15*) is in agreement with the consequences of Reactions 2 and 3. To describe a complete mechanism one would have to write the neutralization reactions of CH_5^+ and $C_2H_5^+$ followed by the reactions of the free radicals so produced, a task at present impossible without considerable speculation.

TABLE 2—*G*-values for Neopentane*

neoC_5H_{12}	−6.6
CH_4	1.8
C_2H_4	0.31
C_2H_6	2.3
C_3H_6	0.26
C_3H_8	0.54
C_4H_8	0.33
isoC_4H_{10}	1.2
isoC_5H_{12}	0.22
neoC_6H_{14}	0.34
H_2	4.3
CH_2 units condensing	16

* 1.7-Mev electrons, 50 mm of Hg, 300° K.

TABLE 3—*G*-values for Ethylene*

Compound	*(75 mm of Hg)*	*(150 mm of Hg)*
C_2H_4	−14.2 ± 2.3	−15.5 ± 1.8
H_2	1.14 ± 0.28	1.28 ± 0.19
CH_4	0.13 ± 0.0+	0.12 ± 0.22
C_2H_2	1.52 ± 0.04	1.46 ± 0.10
C_2H_6	0.40 ± 0.01	0.27 ± 0.10
C_3H_6	0.26 ± 0.02	0.23 ± 0.04
C_3H_8	0.33 ± 0.02	0.11 ± 0.03
n-C_4H_{10}	0.50 ± 0.03	0.48 ± 0.05
cis-C_4H_8-2	0.21 ± 0.12	0.12 ± 0.04
trans-C_4H_8-2	0.12 ± 0.02	0.14 ± 0.05
l-C_4H_8 (or iso)	0.17 ± 0.04	0.14 ± 0.04
n-C_5H_{12}	0.13 ± 0.05	0.06 ± 0.02
n-C_6H_{14}	0.16 ± 0.06	0.13 ± 0.04

* Irradiated at 25° C and 75 mm of Hg and 150 mm of Hg.

Neopentane

The gaseous products formed in 1.7-Mev electron irradiation of neopentane (*16*) and their *G*-values are shown in Table 2. No compounds heavier than neohexane are found in the gas phase, but some liquid is formed in the reaction. In large-dose experiments this liquid is visible on the inner walls of the reaction vessel, but we have made no effort to recover it. Atomic material balances on the gaseous products indicate that the empirical formula of the liquid is C_nH_{2n}.

The results in Table 2 show that reactivity of neopentane under irradiation is similar to that of other saturated hydrocarbons (*17*). Our present knowledge of ion-molecule reactions in neopentane and ion-electron neutralization reactions in general, added to the obvious complexity of the reaction, precludes writing a detailed mechanism. Some features stand out, however.

The most abundant ion in the neopentane mass spectrum has mass 57; thus it is the tertiary butyl ion, $C(CH_3)_3^+$. For the predominant reaction following ionization in the primary act, therefore, we can write

$$C(CH_3)_4^+ \rightarrow C(CH_3)_3^+ + CH_3 \quad (3)$$

The methyl radical has been demonstrated to be the most prevalent free radical in irradiated neopentane (*18*); this experimental fact supports Reaction 3. Presence of methyl radicals immediately suggests that methane and ethane are formed by the usual reactions of abstraction and combination, that is in the following ways

$$CH_3 + C(CH_3)_4 \rightarrow CH_4 + (CH_2)_3CCH_2 \quad (4)$$
$$CH_3 + CH_3 \rightarrow C_2H_6 \quad (5)$$

Rates of formation of methane and ethane can be obtained, of course, from the *G*-values (Table 2) and the energy absorption rate. *If* methane and ethane are formed solely by Reactions 4 and 5, the specific-reaction-rate ratio $k_4/k_5^{1/2}$ can be calculated from the equation

$$\frac{k_4}{k_5^{1/2}} = \frac{R(CH_4)}{R^{1/2}(C_2H_6)} \frac{1}{[C_5H_{12}]} = \frac{G(CH_4)Q_a^{1/2}}{10G^{1/2}(C_2H_6)} \frac{1}{[C_5H_{12}]} \quad (6)$$

(R is rate of formation of the substance indicated; Q_a is rate of energy absorption; the expression in brackets represents concentration of C_5H_{12}.) The computed value of $k_4/k_5^{1/2}$ is 8.5×10^{-13} $(cm^3/molecule/sec)^{1/2}$.

In a study of acetone photolysis in the presence of neopentane—a situation in which methane and ethane could hardly be formed by processes other than Reactions 4 and 5—$k_4/k_5^{1/2}$ was 2.1×10^{-15} (*19*). Our value is greater by a factor of ~400. This means at least that methane is not produced solely by Reactions 4 and 5. Thus we are forced to conclude either that reactions other than free-radical ones are producing methane or else that the methyl radicals are highly excited.

Ethylene

Gaseous products and *G*-values from irradiation of ethylene at initial pres-

TABLE 4—Effect of Argon on Ethylene Radiolysis

Component	*G-value for Indicated Partial Pressure of Argon*			
	0	*75 mm*	*150 mm*	*225 mm*
C_2H_4	−14.2	−25.0	−40.1	−41.6
C_2H_2	1.52	2.98	3.61	4.32
C_2H_6	0.396	0.585	0.824	0.790
n-C_4H_{10}	0.505	0.893	1.03	1.14

sures of 75 and 150 mm Hg are shown in Table 3. Despite an apparent inconsistency in the results for propane and ethane, the course of the reaction appears independent of initial pressure.

The reaction is clearly very complex; observed gaseous products account for only about one-third of the ethylene that reacts. The other two-thirds must proceed to low-vapor-pressure polymeric material not detected in the gas phase.

Mass-spectrometer studies (*11, 13*) of ethylene have found many ion-molecule reactions, all of which have the usual extremely large specific reaction rate ($\sim 10^{-9}$ cm³/molecule/sec). The reactions found are

$$C_2H_4^+ + C_2H_4 \rightarrow C_4H_8^+ \begin{cases} \rightarrow C_3H_5^+ + CH_3 & (7) \\ \rightarrow C_4H_7^+ + H & (8) \end{cases}$$

$$C_2H_2^+ + C_2H_4 \rightarrow C_4H_6^+ \begin{cases} \rightarrow C_3H_3^+ + CH_3 & (9) \\ \rightarrow C_4H_5^+ + H & (10) \end{cases}$$

$$C_2H_3^+ + C_2H_4 \rightarrow C_2H_5^+ + C_2H_2 \quad (11)$$

$$C_2H^+ + C_2H_4 \rightarrow C_4H_3^+ + H_2 \quad (12)$$

$$C_2^+ + C_2H_4 \rightarrow C_4H_2^+ + H_2 \quad (13)$$

We think that the key to understanding the radiation chemistry of ethylene lies in Reactions 7–13 and subsequent reactions of free radicals produced. This applies to both ion-molecule reactions themselves and neutralization reactions of product ions. Unfortunately we have not yet been successful in relating ion-molecule reactions and their consequences to the observed results of ethylene radiolysis.

Inert-gas effect. The effect of an inert gas on ethylene radiolysis is indeed interesting. Table 4 shows results of irradiations in which different amounts of argon were added to 75-mm ethylene. *G*-values shown in the table are calculated from primary electron-beam energy absorbed by ethylene. The increase in *G* calculated in this manner is evidence of interaction between argon and ethylene; energy is somehow transferred from argon to ethylene by either charge transfer or excitation. The transfer manifests itself as an acceleration in ethylene consumption. Such effects have been reported previously in acetylene, butadiene and inorganic gases (*1, 20*).

The surprising thing here is that there is no really large change in the course of the reaction, at least with respect to ethylene consumption and major product formation.

To find the relation between *G*-values and total absorbed energy (ethylene and argon) we have renormalized the values of Table 4, multiplying each column by the factor required to make $G(n\text{-}C_4H_{10})$ equal to 1. The result is Table 5.

Constancy along horizontal rows indicates that it does not matter whether energy is absorbed by ethylene directly or indirectly through some transfer from the argon. This suggests that distribution of entities derived from ethylene and responsible for the observed reaction is the same whether ethylene receives initial energy from the ionizing radiation or argon—ions, excited atoms or both. We feel that this is evidence, admittedly not compelling, that the major argon-ethylene interaction that leads to reaction is one of ionization of ethylene by argon.

Propane-ethylene mixtures. We have carried out irradiations of mixtures of propane and ethylene to examine the effect of high-energy radiation on such a gaseous alkylation system at high temperatures and pressures. Table 6 shows the *G*-values, obtained by extrapolation to zero conversion, for typical conditions of temperature, pressure and radiation intensity. Energy yields of major products in this system are functions of temperature, intensity and pressure.

TABLE 5—Renormalized *G*'s for Ethylene

Component	*G-value for Indicated Partial Pressure of Argon*			
	0	*75 mm*	*150 mm*	*225 mm*
C_2H_4	−28	−30	−39	−36
C_2H_2	3.0	3.5	3.5	3.8
C_2H_6	0.78	0.70	0.80	0.69
n-C_4H_{10}	1.0	1.0	1.0	1.0

TABLE 6—*G*-Values in Propane-Ethylene System*

H_2	2.0
CH_4	7.7
C_2H_4	−93.6
C_2H_6	7.9
C_3H_6	1.9
i-C_4H_{10}	2.8
n-C_4H_{10}	4.0
i-C_5H_{12}	42.8
n-C_5H_{12}	8.6
Other†	12.2

* Initial ethylene concentration, 8.5 ± 1.5 mole %; temperature, 650° F; pressure, 500 psig; dose rate, 1.89×10^{15} ev/cm³/min; 71.3 mr/hr.

† Approximately 50% is butenes; the rest is from 2,3-dimethyl butane, n-hexane, and pentenes in their respective order of abundance.

Figure 4 shows that the *G*-value for the direct alkylation product, pentane (or C_4^+ material), is inversely proportional to the square root of the rate of absorption of energy and directly proportional to the ½ power of total pressure. The approximate temperature coefficient observed for pentane formation corresponds to an activation energy of about 13,000 cal/mole.

So little is known about radiation-induced-reactions of propane and ethylene, even alone, and the reaction between them is so complex that it is clearly impossible to attempt to write a detailed mechanism. There are some features, however, that deserve

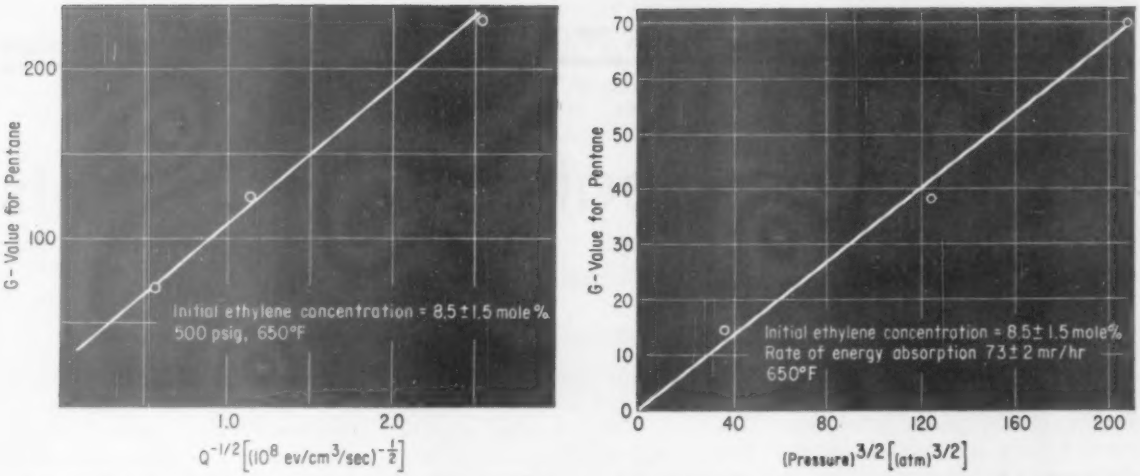


FIG. 4. G-VALUE FOR PENTANE is inversely proportional to square root of dose rate and directly proportional to 3/2 power of total pressure in irradiated mixture of argon and ethylene. Possible mechanism is that of Eqs. 14–19 in text

comment, and since knowledge of gaseous ion reactions in this system is practically nonexistent, I will discuss these features only in terms of free radicals.

Dependence of pentane yield on energy absorption rate suggests the usual type of gas-phase free-radical chain in which radicals are formed in pairs, destroyed in processes that are second-order in radicals and propagated in processes that are first-order in radicals. The effect of total pressure on yields and the appearance of butylenes and propylene in the products indicate that unimolecular radical decompositions must be included. The agreement of the temperature coefficient of pentane formation with the expected activation energy of hydrogen-atom abstraction from propane by a pentyl radical appears to indicate that one of the propagation steps is such an atom abstraction. Thus the experimental observations are consistent with the following scheme. It is proposed only to express a description of the main features of the reaction. It is by no means a detailed mechanism, and it most probably is not a unique one.

$$C_3H_8 \rightsquigarrow 2R\cdot \quad (14)$$

$$R\cdot + C_3H_8 \rightarrow RH + C_3H_7\cdot \quad (15)$$

$$C_3H_7\cdot + C_2H_4 \rightarrow C_5H_{11}\cdot \quad (16)$$

$$C_5H_{11}\cdot + C_3H_8 \rightarrow C_5H_{12} + C_3H_7\cdot \quad (17)$$

$$C_5H_{11} \rightarrow \text{olefin} + R\cdot' \quad (18)$$

$$2R\cdot \rightarrow \text{termination} \quad (19)$$

In Step 14 radicals formed by the action of radiation on propane are not specified because their identity is not known. It is probable, however, that under the conditions of the experiments (high propane-to-ethylene ratios) a large fraction of these radicals will react immediately with propane by Step 15 to form the propyl radical. Formation of pentane proceeds through the chain-propagation steps 16 and 17, with the temperature coefficient dictated by activation-energy requirements of Step 17. Reaction 18 indicates that the pentyl radical can decompose to an olefin and a smaller radical R′, rather than react by Step 17. The chain is terminated by recombination of two free radicals, regardless of their identity (Step 19).

Application of the usual steady-state approximation and assumption of fairly long chains lead to the following expression for dependence of pentane yield on radiation intensity and total pressure (at a given composition): $G(C_5) = KP^{3/2}/I^{1/2}$ (K is a constant; P is total pressure of gas mixture; I is incident radiation intensity). Figure 4 shows that the mechanism is at least consistent with experimental observations.

BIBLIOGRAPHY

1. S. C. Lind, "Chemical Effects of Alpha Particles and Electrons" (Reinhold Publishing Corp., New York, 1928)
2. L. M. Dorfman, F. J. Shipko, *J. Am. Chem. Soc.* **77,** 4723 (1955)
3. S. C. Lind, D. C. Bardwell, J. H. Perry, *J. Am. Chem. Soc.* **48,** 1556 (1926)
4. C. Rosenblum, *J. Phys. Chem.* **52,** 474 (1948)
5. W. Heitler, "Quantum Theory of Radiation," 3rd ed., pp. 368–370 (Oxford University Press, London, 1954)
6. R. E. Honig, C. W. Sheppard, *J. Phys. Chem.* **50,** 119 (1946)
7. F. W. Lampe, *J. Am. Chem. Soc.* **79,** 1055 (1957)
8. W. T. Jesse, J. Sadauskis, *Phys. Rev.* **97,** 1688 (1955)
9. V. L. Tal'roze, A. K. Lyubimova, *Doklady Akad. Nauk. S.S.S.R.* **86,** 909 (1952)
10. D. P. Stevenson, D. O. Schissler, *J. Chem. Phys.* **23,** 1353 (1955)
11. D. O. Schissler, D. P. Stevenson, *J. Chem. Phys.* **24,** 926 (1956)
12. G. G. Meisels, W. H. Hamill, R. R. Williams, *J. Chem. Phys.* **25,** 790 (1956)
13. F. H. Field, J. L. Franklin, F. W. Lampe, *J. Am. Chem. Soc.* **79,** 2419 (1957); **79,** 2665 (1957)
14. M. A. Biondi, S. C. Brown, *Phys. Rev.* **76,** 1697 (1949)
15. G. G. Meisels, W. H. Hamill, R. R. Williams, *J. Phys. Chem.* **61,** 1456 (1957)
16. F. W. Lampe, *J. Phys. Chem.* **61,** 1015 (1957)
17. B. M. Tolbert, R. M. Lemmon, *Radiation Research* **3,** 52 (1955)
18. L. H. Gevantman, R. R. Williams, *J. Phys. Chem.* **56,** 569 (1952)
19. A. F. Trotman-Dickenson, J. R. Birchard, E. W R. Steacie, *J. Chem. Phys.* **19,** 163 (1951)
20. R. C. Palmer, D. C. Bardwell, paper presented at the 134th National Meeting of the American Chemical Society, Chicago, Sept. 7–12, 1958

Gas Dictionary

butane	$CH_3(CH_2)_2CH_3$
butylene (butene) (for example, 1-butene	$CH_3CH_2CH{:}CH_2$)
ethane	CH_3CH_3
ethylene	CH_2CH_2
neohexane (2,2-dimethyl butane)	$(CH_3)_3CCH_2CH_3$
neopentane (2,2-dimethyl propane)	$(CH_3)_4C$
pentane	$CH_3(CH_2)_3CH_3$
propane	$CH_3CH_2CH_3$
propylene (propene)	$CH_2{:}CHCH_3$

Conduction Heat-Flow Transients

By JOSEPH S. HUCKS* and A. L. GAINES, *Combustion Engineering, Inc., Chattanooga, Tennessee*

REACTOR DESIGNERS require information about transient conduction heat flow in two major areas: (1) thermal-stress analysis and (2) heating- and cooling-rate requirements. This information can be obtained directly and rapidly (within the limitations noted below) from the accompanying curves for the two most common types of fluid-temperature change, i.e., instantaneous change, or "step" (black curves in figure), and linear change, or "ramp" (white curves in figure).

The effects from a succession or combination of step or ramp temperature changes at a fluid-wall boundary may be determined by superposition of data from the curves.

Limitations

- Boundary at $\xi = 1$ is perfectly insulated.
- Fluid-temperature change occurs at $\xi = 0$.
- For shells the ratio of radius of curvature to wall thickness is large.
- Material thermophysical properties are evaluated at the mean temperature of the range covered.

The conditions encountered in reality rarely conform exactly to the above limitations, and hence the boundary conditions of the "heat-flow equation" are not rigorously observed; however, investigations (*1–3*) show that in ordinary circumstances the results will be reasonably conservative.

Examples

Determine the maximum biaxial thermal stress (away from edge effects) which develops in an 8-ft-i.d. pressure-vessel wall under the following conditions:

- Wall thickness = 6 in.
- Thermal diffusivity = 0.577 ft²/hr.
- $E\alpha'/(1 - \nu) = 287$ psi/° F.
- $T_0 = 500°$ F.
- Outer surface insulated.
- Fluid temperature drops to 100° F at 500° F/hr. Flow is such that negligible resistance to heat flow exists at the fluid-wall boundary.

$$t = 400° \text{ F}/500° \text{ F/hr} = 0.8 \text{ hr}$$

$$N_{F_{o(\phi)}} = \alpha t/b^2 = (0.577)(0.8)/(0.5)^2 = 1.85$$

From Fig. 2, $\phi_{avg} = 0.825$.

$$T_{avg} = mt\phi_{avg} = 400(0.825) = 330° \text{ F}$$

$$\sigma = [E\alpha'/(1 - \nu)]\,(T_{avg} - T) = (287)(330 - 100) = 66{,}000 \text{ psi}$$

The maximum biaxial thermal stress (away from edge effects) will occur in the plate or shell at the fluid boundary at the end of the temperature transient (compressive stress for an increase in temperature and tensile stress for decrease in temperature). For a step temperature change, from isothermal conditions, the maximum biaxial thermal stress is simply $[E\alpha'/(1 - \nu)]\,(T_s - T_0)$ for the conditions cited.

Liquid sodium flows through a well-insulated 8-in. pipe (schedule 40 AISI type 347 SS). What biaxial thermal stress is developed in the pipe wall if:

- Wall thickness = 0.322 in.
- $E\alpha'/(1 - \nu) = 379$ psi/° F.
- Sodium temperature changes with time (at the pipe inner surface) as:

$t_0 = 0$ sec	$T_0 = 0°$ F
$t_1 = 0.437$ sec	$T_1 = 360°$ F
$t_2 = 0.812$ sec	$T_2 = 420°$ F
$t_3 = 1.312$ sec	$T_3 = 430°$ F

From this data we determine:

Time	m (° F/sec)	$N_{F_{o(\phi)}}$	ϕ_{avg}
$t_0 < t < t_1$	824	0.0344	0.132
$t_1 < t < t_2$	160	0.0636	0.181
$t_2 < t < t_3$	20	0.1032	0.240

* PRESENT ADDRESS: Windsor, Conn.

Symbols

b = sectional thickness (ft)
E = Young's modulus (psi)
m = rate of temperature change (° F/hr)
t = time (hr)
mt = linear temperature change at $\xi = 0$ (° F)
x = point distance (ft)
T = temperature (° F)
$T_{avg} = mt\phi_{avg}$ or $\Delta T_i\theta_{avg}$ = average temperature (° F)
T_0 = initial temperature (° F)
ΔT_i = instantaneous temperature change at $\xi = 0$ (° F)
$N_{F_o} = \alpha t/b^2$ = Fourier modulus
α = material thermal diffusivity (ft²/hr)
$\theta = (T_x \pm T_0)/\Delta T_i$ = dimensionless instantaneous-temperature change ratio ($\theta = 1$ at $\xi = 0$)
$\phi = (T_x \pm T_0)/mt$ = dimensionless linear-temperature-change ratio ($\phi = 1$ at $\xi = 0$)
$\xi = x/b$ = distance ratio
$\sigma = [E\alpha'/(1 - \nu)]\,(T_{avg} - T_x)$ = biaxial thermal stress*
α' = coefficient of linear thermal expansion (in./in./° F)
ν = Poisson's ratio

* $E\alpha'/(1 - \nu) = 360$ psi/° F for austenitic and 220 psi/° F for ferritic steels (approx).

and

$$T_{avg} = (m_1)(t_3)(\phi_{avg3}) - (m_1 - m_2)(t_3 - t_1)(\phi_{avg2} - \phi_{avg1}) - (m_3 - m_2)(t_3 - t_2)(\phi_{avg3} - \phi_{avg2}) = 191^\circ \text{ F}$$

$$\sigma = [E\alpha'/(1 - \nu)]\,(T_{avg} - T) = (379)(191 - 430) = -90{,}500 \text{ psi}$$

The vessel in the first example is allowed to reach uniform temperature at 100° F; then a step in fluid temperature of 400° F is made. Approximately how long will it take for the insulated outer surface of the vessel to reach 300°?

$$T = T_0 + \Delta T_i\,\theta$$
$$300 = 100 + 400\theta$$
$$\theta = 0.500$$

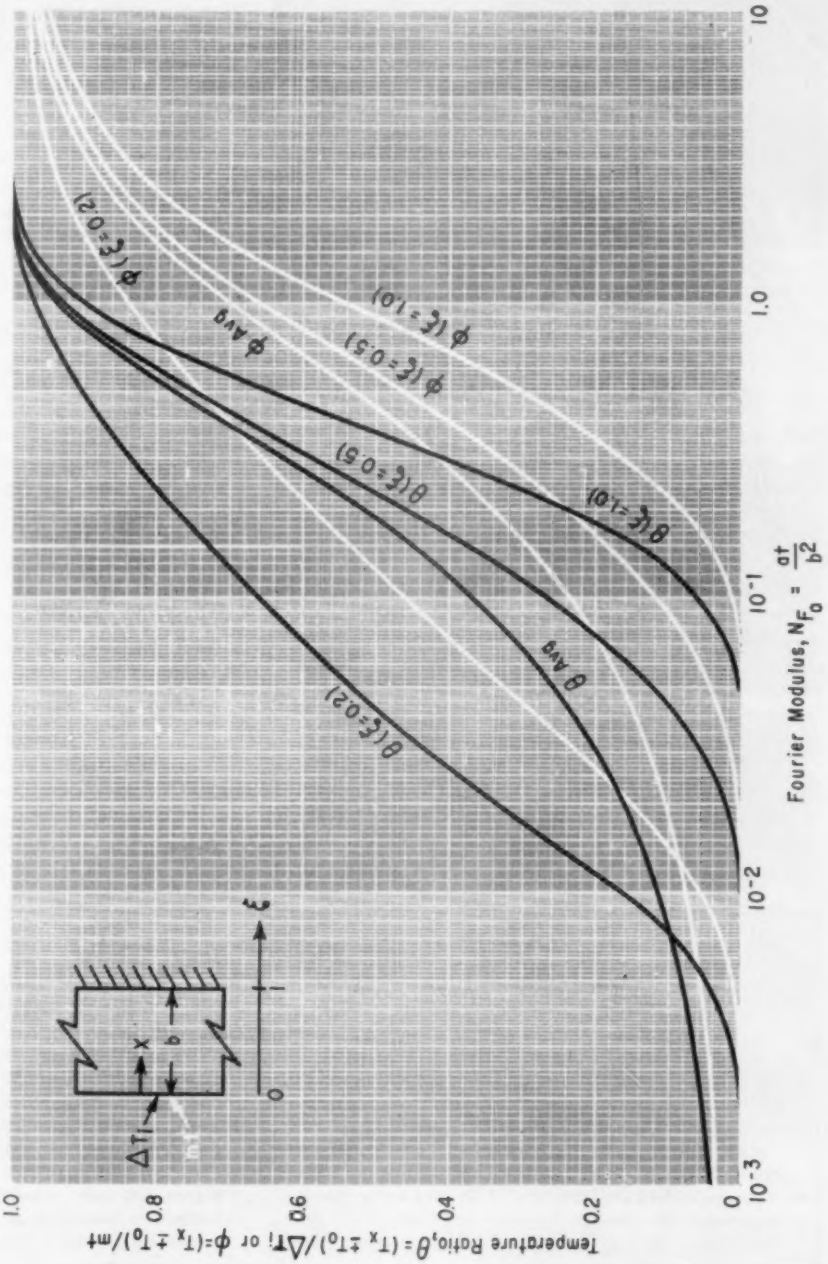
From Fig. 1, $\theta = 0.5$, $\xi = 1.0$, $N_{Fo} = 0.375 = \alpha t/b^2$

$$t = (0.375)(b^2)/\alpha = (0.375)(0.25)/0.577 = 0.163 \text{ hr}$$

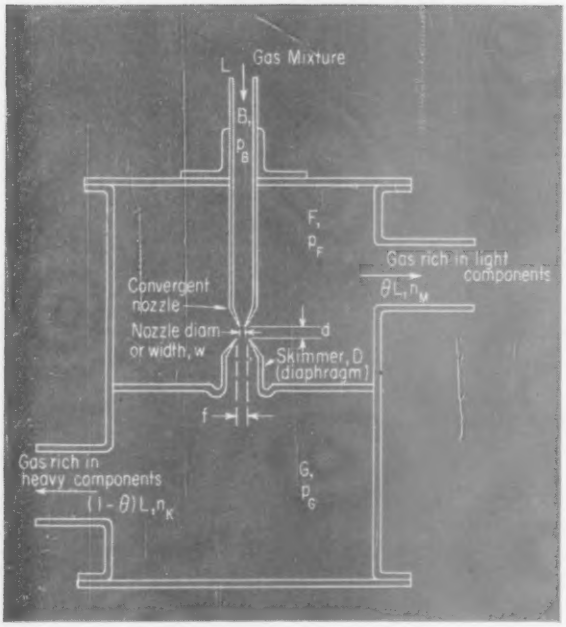
We wish to acknowledge the assistance of the members of the former Thermodynamics Group, Nuclear Components Division, Combustion Engineering, Inc.

BIBLIOGRAPHY

1. J. S. Hucks, A. D. Gaines. An analytical method of predicting temperature gradients in thick-walled pressure vessels, ASME Paper 57-A-231
2. Y. S. Tang. Transient temperature responses and elastic thermal stresses on asymmetrical heated plates and shells, ASME Paper 58-A-216
3. N. E. Friedmann, "Quasilinear Heat Flow," Trans. ASME **80**, 1958



TEMPERATURE VARIATION with time parameter $\alpha t/b^2$ at various positions within slab following surface temperature change. Black curves give temperature ratio θ for step change, white curves give temperature ratio ϕ for ramp change



Uranium Isotope

This new method of enriching UF_6 requires more invested capital and more operating power per stage than do today's diffusion plants, but promises greater reliability and higher separation per stage

FIG. 1. NOZZLE SEPARATION UNIT. Gas expanding from convergent nozzle is separated into two regions by skimmer

By MYRON LEVOY, *Reaction Motors Div., Thiokol Chemical Corp., Denville, New Jersey*

NOZZLE SEPARATION of isotopes is a possible alternative to the conventional barrier diffusion process for enriching uranium in the gaseous UF_6 state (see box). Although it was first discovered in 1948 by S. P. Dickens (*1*), the process has only been given serious consideration since it was rediscovered recently by E. W. Becker and his co-workers in Marburg, West Germany (*2–6, 8, 12*). Becker's group has performed nozzle separation experiments with UF_6 that show that the separation effect per stage is the same order of magnitude as in the conventional process. Also, more recent work by J. W. Eerkens at the University of California (*7, 9–11*) on a supersonic jet holds out the possibilities of separation efficiencies 2–4 times higher than Becker's.

The general principle of nozzle separation is illustrated in Fig. 1. Following Becker's description (*12*), a gaseous mixture of isotopes to be separated is fed under pressure P_B at molar flow rate L to a nozzle from which the gas emerges as an expanding supersonic jet. A skimmer (diaphragm D) separates the jet into a peripheral region (θL) and a core region $(1 - \theta)L$. The lighter component of the gas is more concentrated in the peripheral portion of the jet and the heavier component in the core region. The gas in the two regions is pumped away under pressure P_F and P_G, respectively.

We define the elementary separation effect ϵ_A by

$$\epsilon_A = \frac{n_M(1 - n_K)}{n_K(1 - n_M)} - 1$$

where n_M and n_K are the mole fractions of the lighter component of a binary mixture in the peripheral region and the core region, respectively. The separation effect for the nozzle separation process has the same order of magnitude as the gaseous diffusion process (*12*). For example, at $\theta = 0.20$, $\epsilon_A = 0.005$ for case 1 of Fig. 3 compared to an

Uranium Enrichment Derby

When the U. S. went into its crash program in 1945 to produce enriched U, it started out by considering at least three different methods of physical separation (gaseous diffusion, centrifugal and electromagnetic). As we know, the gaseous diffusion method soon won this competition so that today the AEC's entire output of enriched U is produced by this method.

Today newcomers to the enrichment field—commercial companies in the U. S. and Europe—are starting the contest all over again (NU, Oct. '59, 17). This time the contenders with gaseous diffusion are the resurrected centrifugal separation process and the more recently discovered nozzle separation method, which is described in this article.

Both eliminate the need for delicate and costly diffusion barriers but neither has yet demonstrated that a full-scale plant would offer an over-all cost advantage. The accompanying article reviews the status of the nozzle separation method. In the centrifugal method, the rotating centrifuge would involve higher maintenance and replacement costs than the static nozzle or diffusion barrier. In compensation, new centrifuge materials and designs now permit much higher rotational velocities and hence a higher separation factor. NUCLEONICS will publish a review article on the centrifuge process in a subsequent issue.

Separation by Nozzles

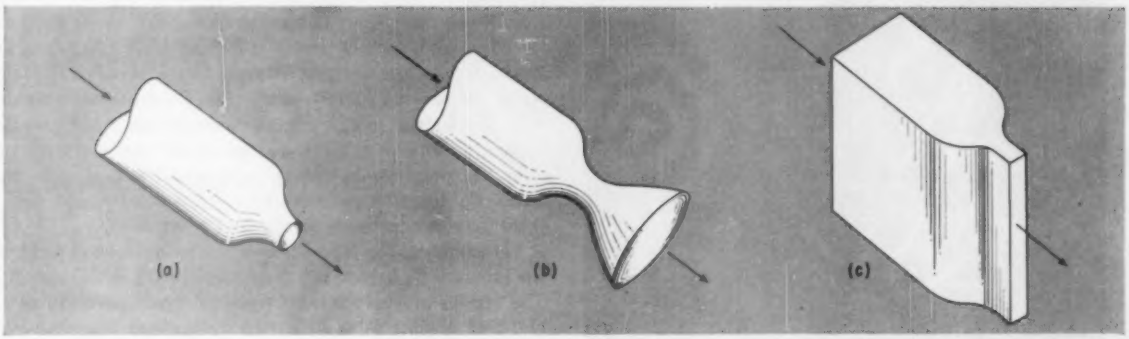


FIG. 2. THREE NOZZLE TYPES. Nozzles (a) and (c) were used in tests by Becker. Nozzle (b) costs more and offers no advantage

ideal ϵ_a of 0.0043 for gaseous diffusion.*

As with the gaseous-diffusion process, one would construct a separation plant by arranging a number of jet-skimmer combinations in series (and parallel). Enriched peripheral gas from the first nozzle would go to a second nozzle for further enrichment and then to a third. The depleted core gas would cycle back to previous nozzles. Applications of interest would include separation of U^{235} from natural uranium, of helium from nitrogen in natural gas and of natural gasoline from natural gas.

Separating Nozzle

The separation of the two components appears to be due to pressure diffusion created by radial pressure gradients in the jet (*1, 5*). To achieve appreciable diffusion, low absolute pressures (of the order of a few mm Hg) are required in the nozzle, chamber, and diaphragm. This leads to high-compression suction volume, that is, large volume of pipes, compressors and valves with consequent high equipment costs (*6, 12*).

Nozzles and diaphragms with small diameters (0.05 to 0.5 mm) attain the same separating effect ϵ_A at higher pressures and hence are economically favorable (*12*). Decreasing the nozzle increases the ratio of jet surface area to volume and the ratio of gas kinetic mean free path to nozzle diameter, both of which give higher ϵ_A. Also, it gives a small Reynolds number, which reduces turbulence.

The nozzle construction may be relatively simple (see Fig. 2). For most practical conditions studied, a divergent portion seems to hinder rather than help the separation (*5*) and only adds to the capital cost of the system.

With small diameters, many nozzles would be required, with associated skimmers and collection chambers to achieve reasonable gas throughputs. S. P. Dickens et al have described such a system (*1*). A slit-type nozzle (see Fig. 2) used by Becker et al (*5, 12*) leads to a decrease in the required number of nozzle elements by maintaining small equivalent diameters with a relatively high gas throughput per element.

Uranium Isotope Separation

Becker and his co-workers have carried out work on the separation of uranium isotopes over the past three years

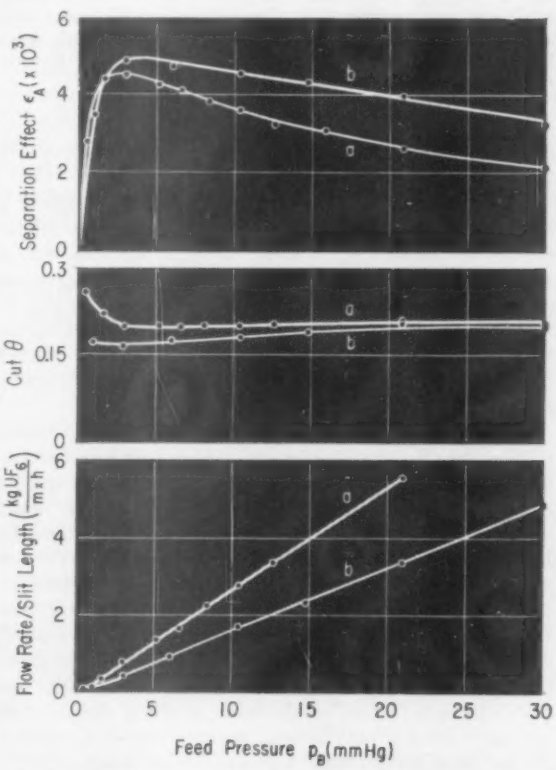


FIG. 3. PROCESS PARAMETERS vs. feed pressure P_B for P_T and $P_C < 0.1$ mm Hg; *a* and *b* are geometric parameters (see text)

* $\epsilon_a = \left[\frac{n_M}{(1 - n_M)} \frac{(1 - n_0)}{n_0}\right] - 1$, where subscript 0 refers to feed gas. In the discussion here, ϵ_A is about 10% greater than ϵ_a.

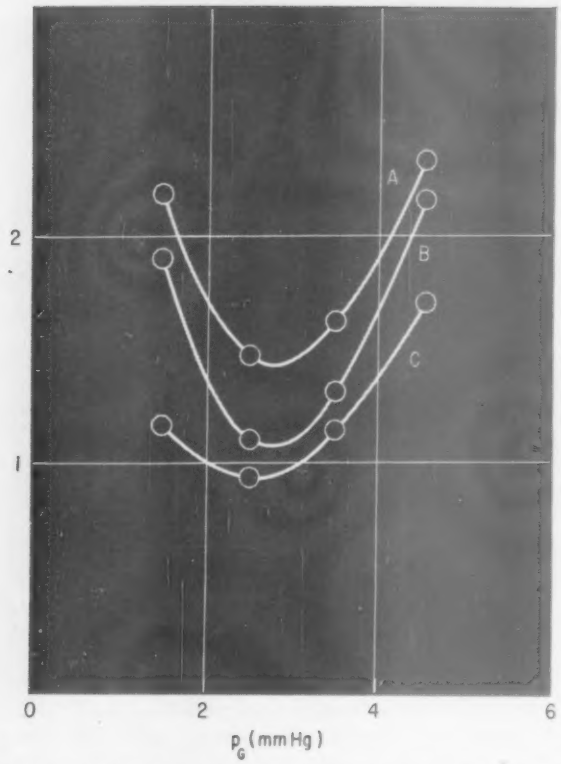


FIG. 4. NOZZLE PARAMETERS vs. pressure P_G of exhaust region G. Curve A is specific ideal isothermal-compession power (10^3 kwh/gMol); curve B is specific suction volume ($10^7 m^3$/gMol); curve C is specific slit length (10^5 mh/gMol). Pressures P_B and P_F have the values 20 mm Hg and 0.5 mm Hg

(*4, 5, 12*), first with natural mixtures of argon isotopes and then with UF_6.

On the basis of earlier experiments, they designed a separation element with a slit nozzle and initiated systematic studies on the separation of the uranium isotopes with a sensitive mass spectrometer (*12*). To find the optimum operating conditions, the following parameters (see Fig. 1) must be varied: w, f, d, P_B, P_F, P_G. The experiments so far have been limited to two sets of dimensions: (a) $w = 0.085$ mm; $f = 0.29$ mm; and $d = 0.011$ mm and (b) $w = 0.045$ mm; $f = 0.19$ mm; and $d = 0.081$ mm.

Figure 3 shows the variation of elementary separation effect ϵ_A, the cut θ, and the gas flow L per unit time and per unit slit length with feed pressure P_B. Pressures P_F and P_G were below 0.1 mm Hg. Figure 3 shows that, at higher values of P_B, ϵ_A decreases with increasing P_B. This happens because in this pressure range the pressure-diffusion current varies relatively little with P_B while the current L of feed gas increases with increasing pressure. Because the width of the nozzle in experiment (b) is about one-half of that in experiment (a), (b) gives the same separation effect as (a) at nearly twice the pressure [the ratio of gas kinetic mean free path to nozzle width for (b) remains about the same as for (a)]. Since a high system pressure favors economics, Becker plans further tests with the narrow nozzle (*12*).

Other runs, with variable P_F and P_G and $P_B = 20$ mm Hg, indicate that ϵ_A decreases with increasing P_F (*12*). As P_F increases, the pressure gradient that causes diffusion decreases. The separation is considerably less sensitive toward an increase of P_G behind the diaphragm since this pressure does not directly affect the diffusion phenomena.

Becker has also done some work toward optimizing overall plant economics (*12*). The parameters of merit were the specific ideal isothermal-compression power, specific compressor suction volume (proportional to equipment volume), and specific nozzle slit length (*5, 12, 13, 14*). These parameters are proportional to the separation plant costs: the specific compression power is proportional to the cost of electric energy for the compressors; the specific suction volume is proportional to capital and maintenance costs of compressors, valves, and pipes; and the specific nozzle slot length is proportional to capital and maintenance costs for slot nozzles, housings, and controls (*5*).

For example, Fig. 4 shows how the parameters depend on the pressure P_G behind the diaphragm for $P_F = 0.5$ mm Hg. The curves are calculated from experimental values of ϵ_A and θ at varying P_F and P_G. In the pressure range investigated all these curves have definite minima which by coincidence appear at the same value of $P_G = 2.8$ mm Hg.

With other values of P_F, corresponding curves are similar, and by comparing their minima one can obtain an optimum value of P_F for the three specific cost factors. For example, specific suction volume is a minimum when $P_F = 0.5$ mm Hg. For the other specific cost factors, slightly lower values of P_F are favorable. Some weighted compromise between the three is necessary.

Becker concludes from this work that the specific ideal isothermal-compression power of about 1.5×10^3 kwh/g mol (from Fig. 4) might be somewhat higher than the corresponding value for the gaseous diffusion process—which means the cost of plant power would be higher. However, the greatest weakness of the nozzle process so far is the high suction volume of the compressors. On the other hand, the freedom from porous membranes is apt to assure a high degree of reliability and appears to be an advantage of the nozzle process (*12*). Also, since the work with UF_6 has just started, further improvements may be expected.

BASIC THEORY

The nozzle separation phenomenon apparently depends primarily on pressure diffusion (*5*). Sharp radial pressure gradients, which exist at the periphery of the expanding jet just beyond the nozzle exit, cause radial diffusion.

Rousso and Kochendorfer at NACA (*16*) have observed pressure gradients of this kind in jets at relatively high pressures, with total pressure probes. The gradient in their tests decreases rapidly with axial distance from the nozzle exit. For example, with a nozzle pressure ratio (chamber pressure/ambient pressure) of 10, the gradient at 2 diameters from the exit is about 0.3 of the gradient at 1 diameter. (Both gradients are taken close to the jet periphery.)

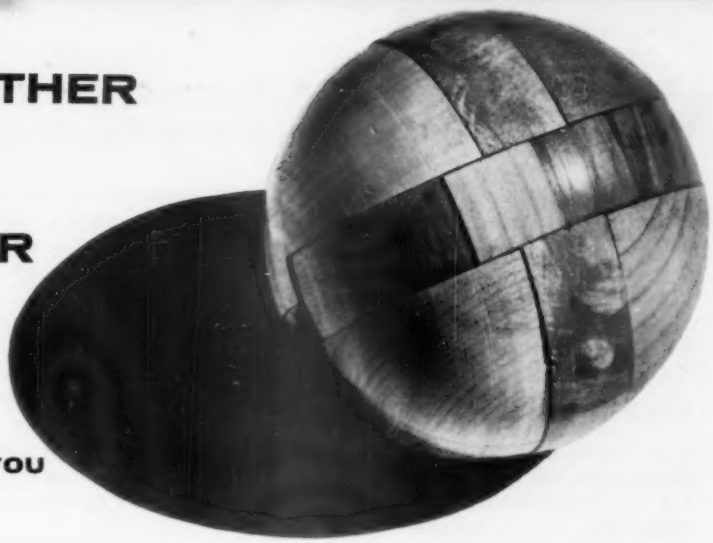
Optimum Distance

Becker finds for argon isotopes that an optimum axial distance between nozzle and skimmer d exists for maximum separation, ϵ_A (at constant skimming ratio, θ) (*5*). This distance lies between 0.5 and 2.0 diameters, depending on P_B, P_F and P_G.

The following mechanism may partially explain the

(*Continued on page 118*)

AEC PUTS TOGETHER A LONG-RANGE POWER REACTOR PROGRAM



NUCLEONICS DIGESTS IT FOR YOU

The Atomic Energy Commission has charted a course for its civilian power reactor program destined to make nuclear power economic in high-power-cost regions of the U. S. before 1968. A detailed plan for research, development and reactor construction to achieve this has been set forth, complete with timetables and approximate funding levels. The new plan is not intended as a static thing—it will be the subject of continuing reappraisal. Advances in technology and new ideas will need to be considered. Some concepts may be dropped; certain new others may receive increased emphasis. But a precedent of systematic evaluation now exists.

The new program covers only AEC projects and those carried out jointly by AEC and industry. Wholly private activities will therefore fill out the picture further, and AEC encourages such activity.

Program Background

A ten-year program for achieving economically competitive nuclear power was called for and eventually agreed upon in JCAE-AEC negotiations that took place in the final months of Lewis Strauss's tenure as Chairman of AEC. When McCone took over in mid-'58 economic nuclear power within ten years was made an official AEC goal.

Detailed implementation began in June, 1959, with a January, 1960, target date for completion of a report. The massive study required a tremendously complicated and time-consuming effort, and it is a tribute to AEC's hard-working staff that the report, published Feb. 12, missed a severe deadline by less than a fortnight.

A special task force within the civilian power evaluation and planning branch of the Division of Reactor Development was set up to draft the program. First step was to call on eight outside experts in as many reactor concepts to draw up reports on the present economic and technological status of each concept (the concepts are listed below). These reports, written to strict AEC specifications as to definitions, assumptions, etc., and brought to a consistent cost basis by Sargent & Lundy, were then assessed by the AEC task force.

AEC's evaluation branch, in consultation with its advisors in industry and the national laboratories, then staked out the specific technical improvements that could be foreseen for each concept and estimates of the impact these improvements would have on the cost of nuclear power. In each instance the evaluation branch formulated the development program, complete with costs, that would be required to realize improvement.

The new program—first set forth in full detail by AEC at the recent section 202 "state-of-the-industry" hearings held by the Joint Committee on Atomic Energy—is embodied in a series of documents just published by AEC. It is those documents that form the basis for the present NUCLEONICS report.

Program Coverage

AEC's new program concentrates on large power reactors because it is in large sizes that nuclear power plants can most readily prove economic. This doesn't indicate any lessening of AEC interest in small power reactors—a program of this type is also under way.

All eight major reactor concepts that are currently being developed under the civilian reactor program were studied by AEC. Included are: pressurized-water, boiling-water, organic-cooled, sodium-graphite, gas-cooled (enriched fuel), fast-breeder, aqueous homogeneous and heavy-water-moderated.

New concepts are not excluded from consideration but were not subjected to economic evaluation because of the limited state of their development.

In addition to consideration of reactors by concept, the report gave considerable attention to the present state and future direction of nuclear technology as a whole. Fuel, cladding and control materials, chemical reprocessing, waste disposal, reactor physics and test and research reactor needs are among the subjects covered and planned for.

What We've Tried to Do

Faced with the task of condensing 339 pages of report, itself a boildown of volumes of material and months of work, NUCLEONICS' editors decided to concentrate on three aspects: (1) nuclear power economics (pp. 72 and 73); (2) the key problems and construction plans for each concept (pp. 74–81); (3) the role played by current status of fuel-element development, p. 82. These represent some of the highlights of this very significant AEC report.

Nuclear Power Fast Becoming Economic

The gist of AEC's evaluation of the economics of nuclear power—its present status and short-term potential—is given in the table on the opposite page. The picture is a promising one: more than one reactor type can shortly be expected to beat the 7-mill/kwh target figure that AEC chose as representative of high-power-cost regions of the U. S. But AEC's assertions must be understood in terms of the particular assumptions and evaluation procedures it employed.

First Reference Design

AEC's evaluation procedure started with so-called reference designs, one for each of the major established reactor types. These reference designs are given in partial detail in the lower half of the table on the opposite page. The designs do not correspond to particular existing reactors; rather they are extensions of existing designs based on evaluation (as of 1959) of the technical status of that particular reactor type and developments pertinent to it—as if construction of a new reactor of that type were to start in 1960. Thus, for example, the Hallam reactor was chosen as the basis of the sodium-graphite reference design, but, among other things, a new type of heat exchanger, proven since the Hallam design was frozen, was assumed.

The reference design was carried to a point similar to that of a preliminary design or feasibility study. Since the design was for purposes of evaluation, rather than construction, there was no need to carry out the even more detailed analyses that are usually associated with the name reference (or Title I) design. Assurance that the reference design is to be taken seriously is afforded by the fact that these designs were originally staked out (and later reviewed) for each concept by top experts called in by AEC (NU, July '59, p. 17).

Extrapolating in Power

Given the reference designs the next task was to adjust them to a common gross electrical power output of 300 Mwe. This task was performed for the AEC by the architect-engineer Sargent & Lundy, and the methods are reported in detail in their report SL-1674. Capital, fuel-cycle, operating/maintenance and insurance costs were extrapolated separately.

Capital costs. Basic flow diagrams and general arrangement drawings were prepared for each reactor type, based on the reference designs. Cost estimates were then made using Sargent & Lundy's normal estimating practices and using uniform costs, wherever possible. The capital cost portion of all power cost estimates was based on 14% annual fixed charges and 80% capacity factor. Uniform costs were used, with appropriate differences for size, for those components that had the same specifications (such as turbine-generators, condensers, buildings, etc.).

Fuel-cycle costs. To aid the extrapolation, fuel-cycle cost estimates were made for three different core sizes for each reactor type (with the exception of the gas-cooled reactor, for which information was insufficient). The average fuel burnup and fabrication costs used are given in the table on the opposite page and the details of fuel-charge practices are given in the footnote in the table.

Operation and maintenance. Since operation and maintenance represent 10% or less of nuclear-power costs, their extrapolation was handled in simplified manner. Estimates were prepared for a 75- and a 300-Mwe reactor of each type based on actual experience and plans where available (e.g., Shippingport, Indian Point) and on operational requirements. Due notice was taken of the difference among reactor types in this regard.

Insurance. Insurance costs were based on purchase from a pool of $150,000 of nuclear liability insurance per megawatt of thermal capacity plus government indemnity at a cost of $30/Mw with coverage up to $500,000,000. An all-risk nuclear property insurance at rates of the order of $0.35 per $100 of coverage was also assumed.

Extrapolating in Time

Given, as a result of the preceding scaling in power, the current costs for a 300-Mwe reactor of each type, AEC then asked how these costs might be expected to be reduced by further reasonable development. The same reactor concept and fuel cycle as in the reference design were assumed (left to further studies was the matter of the potential of radical changes, such as change in moderator).

AEC's evaluation group sought "to identify apparent areas of improvement whose successful development will reduce the cost of power and to estimate the economic potential of realizing these improvements." AEC assumed successful completion of this development in every case. This all-pervading optimism is balanced, says AEC, by the fact that only readily apparent cost-reducing developments were considered. Implicitly AEC believes that if some developments don't pan out, other cost reductions, which it did not envision, will take place. Also no credit was taken for evolutionary improvements wrought by increased competence, such as shorter construction periods, nor for reduction in component cost owing to increased production.

Clearly estimates of technical improvements and the economic worth of these improvements are sounder for those reactor systems with which we have construction and operating experience. Thus the error in the potential power costs given above increases with inexperience in the concept. The following example from Part II of AEC's Report illustrates the nature of the reductions that are envisioned for the pressurized-water reactor:

Item	*Improvement envisioned*	*Saving (mills/kwh)*
Coolant pumps	Shaft sealed to replace canned	0.11
Pressurizer	Eliminate it	0.03
Vapor container	Reduce: "burp" method, or vapor suppression	0.09
Hot-channel factors	Reduce with chemical control, bulk boiling, flow analysis	0.37
Rod drives	Better engagements	0.05
Fuel cycle	Higher burnup (27,500 → 40,000 Mwd/tonne)	0.52
	Lower fabrication cost ($110 → $70/kg U)	0.31
		1.48

This reduction, when applied to the 9.28-mill/kwh present cost of power from present PWR designs, yields the 7.80 that AEC sees for plants *completed* in 1966.

Nuclear-Power Economics For Seven Reactor Types

	PWR	BWR	OMR	SGR	GCR	D_2O	FBR
AEC predicts these nuclear power costs for tomorrow's 300-Mwe plants...							
Total capital cost ($10⁶)	64.0	64.5 (58.5)††	53.2	67.1	69.5	88.6	65.0
Power costs (mills/kwh)							
Capital charges	4.40	4.31 (3.91)††	3.53	4.47	4.63	5.80	4.43
Fuel cycle**	2.56	2.29 (1.96)	1.83	2.00	2.62	1.21	1.99
Operation and maintenance	0.59	0.61 (0.61)	1.09	0.70	0.49	0.91	0.79
Nuclear insurance	0.25	0.24 (0.23)	0.22	0.25	0.24	0.28	0.25
Total	7.80	7.45 (6.71)	6.67	7.42	7.98	8.20	7.46
...if these development expenditures are made during 1960-1970 ($10⁶)†							
Research and development	27†	59‡‡	72	84	107	90	143
Gross construction	126‡	136	104	165	121	193	179
Net construction§	65	66	38	99	52	106	101
Total gross	153‡	195	176	249	228	283	322
Total net	92‡	125	110	183	159	196	244
Same size plants built today would have these costs...							
Total capital cost ($10⁶)	73.4	78.9	66.0	90.9	114	108	76.5
Power costs (mills/kwh)							
Capital charges	5.05	5.26	4.39	6.05	7.60	7.08	5.10
Fuel cycle**	3.38	3.47	5.72	7.68	3.35	4.22	7.10
Operation and maintenance	0.59	0.61	1.09*	0.70	0.61	0.93	0.79
Nuclear insurance	0.26	0.27	0.25	0.29	0.33	0.30	0.26
Total	9.28	9.61	11.45	14.72	11.89	12.50	13.25
...and a reference design based on these typical reactor parameters							
Heat balance							
Total reactor power [Mw(th)]	810	690	260	240	830	860	440
Gross turbine power [Mw(e)]	213	212	79	80	240	214	160
Net plant power [Mw(e)]	200	200	75	75	200	200	150
Net plant efficiency (%)	24.8	29.0	28.5	30.8	24.1	23.2	34.2
Turbine cycle conditions		Pri. Sec.			(High) (Low)		
Throttle temperature (° F)	480	540 460	550	850	650 450	366	780
Throttle pressure (psig)	555	950 460	585	785	500 100	150	850
Steam flow ($10⁶ lb/hr)	3.03	1.44 1.21	0.936	7.19	1.77 0.785	3.03	1.46
Final feedwater temperature (° F)	340	565 405	360	300	260	251	380
Reactor description: core							
Active diameter (ft)	8.6	10.5	9.5	13.4	50	12	3.0
Active height (ft)	9.0	9.75	9.5	13.5	29	15	2.54
Reactor description: fuel elements							
Burnup (Mwd/metric ton)	13,000	11,000	4,500	11,000	3,000	3,960	15,900
Fuel material	UO_2	UO_2	U(3.5 w/o Mo)	U(10 w/o Mo)	nat. U metal	nat. U metal	U(10 w/o Mo)
Cladding material	ss	Zr-2	Al	ss	magnox	Zr-2	ss
Fuel enrichment (%)	3.34	1.5	1.6	2.85	nat.	nat.	25
Fuel element geometry	rods	rods	cylinder	rods	finned rods	cylinder	rods
Cladding thickness (in.)	0.029	0.030	0.035	—	0.020	0.030	—
Fabrication cost ($/kg U)	110	140	60	110	50	50	480
Reactor description: material inventories							
Fuel (metric tons)	52	66.5	41.4	36.7	274	27.2	0.509
Uranium (metric tons)	41.7	52.3	41	33	274	27.2	0.463
Initial U^{235} (kg)	1390	785	656	940	1970	188	430
Plant-performance data							
Primary coolant outlet temp. (° F)	574	545.3	575	945	710	480	900
Primary coolant inlet temp. (° F)	533	505	490	607	323	414	600
Reactor temperature drop (° F)	41	40.3	85	338	387	66	300
Primary system pressure (psia)	2200	1015	150	atmos.	200	750	115
Primary coolant flow rate ($10⁶ lb/hr)	53.1	1.43	19.8	8.44	28.3	39.6	16.4
Maximum core heat flux ($10⁶ Btu/ft²/hr)	39.5	27.7	11.2	30.2	96.0	77.7	116.7
Average core heat flux ($10⁶ Btu/ft²/hr)	8.618	9.77	2.8	12.1	56.0	33.5	67.5
Max. clad. surface temp. (° F)	636	585	750	1000	730	575	1000
Maximum fuel temperature (° F)	4500	4500	—	1260	1200	880	1050
Core coolant velocity (ft/sec)	14.1	—	15 (max)	11.4 (max)	—	15	31.2
Peak-to-average power ratio	4.55	2.92	4.0	2.5	1.72	2.32	1.44
Core specific power ($10³ kw/metric ton U)	19.5	13.2	6.34	7.27	3030	31.6	947

* Includes organic make-up cost at 13¢/lb.

† Includes research, development and construction funds supplied by private industry in cooperative arrangement with AEC but not private-industry costs outside arrangements with AEC.

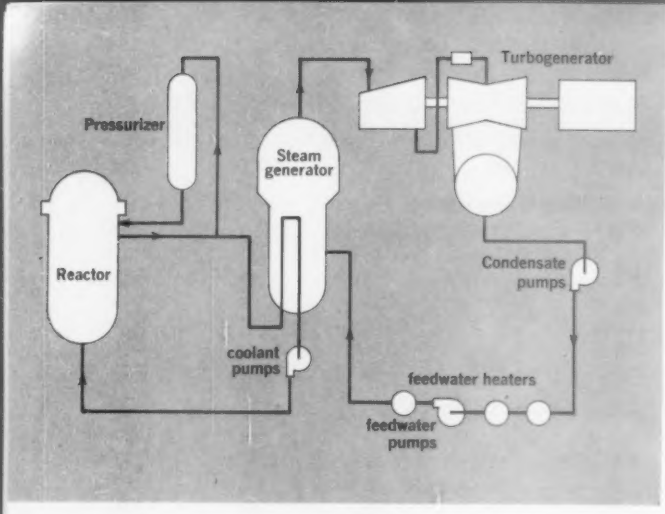
§ Includes cost of test and experimental facilities plus cost for prototype and large power plants that is over cost for conventional plants of the same size.

‡ Does not include estimated 125×10^6 for research and development nor 5×10^6 construction cost required for Shippingport.

** Fuel-cycle assumptions: Reprocessing = $15,300/day (8 + mt of U); AEC schedule for UF_6 cost; Shipping cost (irradiated fuel) = $12.45 kg; Conversion of uranyl nitrate solution to UF_6 = $5.60/kg; Conversion of plutonyl nitrate solution to Pu metal = $1.50/gm; Pu buyback (credit) = $12/gm.

†† Costs with superheat (1,500 psi and 1,000° F); similar reductions in costs would result for pressurized water reactor using superheat.

‡‡ Proposed expenditures for BWR include money for superheat development.



Pressurized-Water Reactor

Large-size (300 Mwe) pressurized-water-reactor plants, if constructed now, should be competitive over their lifetimes in high-cost areas of the U. S. The further development of the concept (see projects listed below) will continue to profit, as it has in the past, from the Navy's ambitious program. The natural circulation prototype to be built at National Reactor Testing Station for the Navy may be of particular interest to small power reactors. Valuable information can also be expected from the Army Reactor Program and the experience with the N. S. Savannah.

Key Problems for This Concept

Fuel development program aims at cheaper fabrication and longer fuel life: Fabrication costs can be reduced by developing improved pelletization techniques that will eliminate the expensive grinding operation and permit longer pellets to be made. Tapered dies in the laboratory have produced long pellets with no "hour-glassing." Control of sintered density will hold the dimensions and may eliminate grinding. Alternative methods such as extrusion of UO_2 in rod form and the swaging of complete fuel rods also show promise.

Better neutron economy (and hence lower fuel cost) would result from thinner cladding. The cladding now must be noncollapsing; should collapsed clad be feasible, wall thickness as low as 0.012 in. may be used. Development of inexpensive, low-cross-section cladding materials such as iron-aluminum materials could also improve cladding costs.

Fuel burnup can, according to burnup data, be extended to at least an average 27,500 Mwd/tonne of U in UO_2 fuels with peaks as high as 50,000–60,000 Mwd/metric ton.

Surface temperature of fuel has been restricted by desire to avoid center melting of fuel rods. Recent fuel-irradiation experiments indicate this need not be a source of serious concern. An increase in power output from 14 kw/ft of fuel rod to perhaps 20 kw/ft could be had if the rod centers are allowed to melt.

Bulk boiling, if permitted in the hottest channels, would lead to an immediate increase in performance. Experimental tests are required to determine the effects of bulk boiling on reactor physics, core stability and heat transfer.

Reactivity control is now done entirely with control-rod shimming; methods of extending control worth might include schemes such as movable fuel sections, burnable poisons and chemical shim through liquid poisons and neutron rectifiers. These improved control methods would also reduce the hot-channel factors and flatten power-distribution.

Materials development would seek out less expensive structural materials to replace stainless steel. First step would be to check carbon steel and low-alloy steel for corrosion rates, system contamination and strength properties.

Components developments which promise cost reductions include:

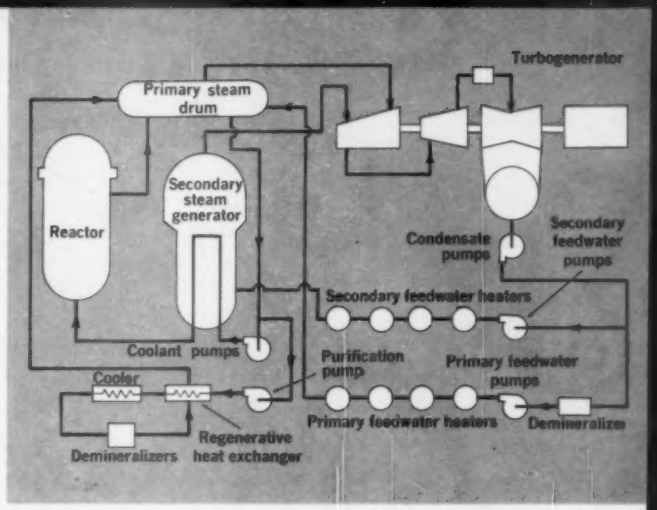
- *Primary coolant pumps*—development of less expensive shaft-seal pumps to replace present canned-rotor pumps.
- *Control-rod drives*—develop improved-engagement magnetic-jack systems.
- *Containment shell*—replace the present conservative design with a "burp" system (in which the initial steam and water release is allowed to escape to the atmosphere) or with a vapor-suppression system (in which the released vapor is cooled and condensed by large supplies of cold water stored within the shell). Since the maximum credible accident does not lead to core melting in most designs, future designs may be able in time to eliminate the shell completely.
- *Pressurizer*—replace the present external electrically heated pressurizer by a steam dome within the reactor vessel.

REACTOR CONSTRUCTION

Existing or Scheduled	Date Critical
Shippingport (60 Mwe) will soon go up in power to 150 Mwe, will continue to test new concepts of seed and blanket elements such as the flat oxide plates in the second core	'57
Yankee (110 Mwe) will feature solution poison for shutdown control	'60
Belgian Reactor-3 (11.5 Mwe)	'60
Indian Point (151 Mwe + 104 Mwe conventional superheat) will use Th-U^{235} fuel mixture	'61
Saxton Hook-On (5 Mwe)	'62
Process-Heat Reactor [40 Mw(th)] will explore the economies of low-temperature, low-pressure process steam	'62
Small Power-Reactor Prototype (16 Mwe + 6 Mwe conventional superheat) will demonstrate feasibility of bulk boiling	'62
SELNI Reactor (165 Mwe) to be built in Italy	'63

AEC's Suggested Program	Date Initiate
Advanced Technology Prototype (? Mwe), if justified by experience with Shippingport, Yankee and Indian Point plants	'63
Spectral-Shift Prototype (50–100 Mwe), if justified by results of current work	?
Remote-Location Prototype (20–30 Mwe) would test reliability of small isolated station	'62

Boiling-Water Reactor



Manufacturers of boiling-water reactors have advised the Commission that a 300-Mwe plant, if constructed now, could compete in high cost fuel areas in the U. S. The advanced stage of boiling-water-reactor development is due in part to our extensive experience with pressurized water. Aside from nuclear superheat, most of the developments foreseen for boiling-water technology will be demonstrated with the reactors that are now operating or are scheduled to be built.

Key Problems for This Concept

Fuel-development essential to the maximum development of boiling and/or boiling superheating reactors includes:

- *High-temperature fuel element* capable of 1,200° F for 10,000 Mwd/t with geometry suitable for superheated steam.
- *Design limits on oxide fuels*—fuel density vs. thermal conductivity and fission-gas release, effects of centerline melting, mechanical support provided by the fuel, thermal resistance between fuel and cladding, performance of unswaged UO_2 and corrosion rates for UO_2 and clad.
- *High heat-flux element* capable of 400,000–500,000 Btu/hr/ft² at power densities of 20–30 kw/kg of U.

Evaluation studies are required for boiling systems that use combinations of the direct or indirect cycles as well as for other variations such as forced plus natural circulation. Also needed are studies of the merits of natural vs. forced circulation and external vs. internal steam separation.

Burnout heat flux analysis of United States and foreign heat-transfer data should be made to improve the very unsatisfactory correlations of factors affecting burnout heat flux in boiling systems and to guide much needed experimental programs on burnout.

Stability analyses of boiling reactors, now a sporadic effort by individuals or small groups, should be the subject of a large coordinated program treating all available data.

Nuclear superheat technology lacks engineering design data, such as material properties, activity carryover in a high-temperature-steam system, arrangement of the core and reactor internals, fuel design and performance, steam separation and shutdown cooling.

In-core instrumentation programs are needed to develop reliable instruments to measure voids, temperatures, pressures, heat fluxes and water level.

Reactivity lifetime, a serious limitation for boiling-water reactors, must be extended without sacrificing neutron economy and power flattening by methods such as neutron rectifiers, movable fuel sections and other control schemes.

Low-suction-head pump—a recirculation pump capable of reliable operation with 10 feet or less of suction head would save the extra piping, supports, foundations and containment volume now required to provide a 30 ft head.

High power density is the ultimate goal of test programs (a) to improve power flattening (control-element type and arrangement, zoned enrichment, steam-void control, burnable poisons and temporary poison shims) and (b) to improve fuel-element design (greater subdivision with minimum increase in fabrication cost).

Vapor containment (see "Containment shell" under PWR)

Physics parametric analysis is required to evaluate nuclear superheat cores over a broad range of temperatures, volume fractions and other core parameters.

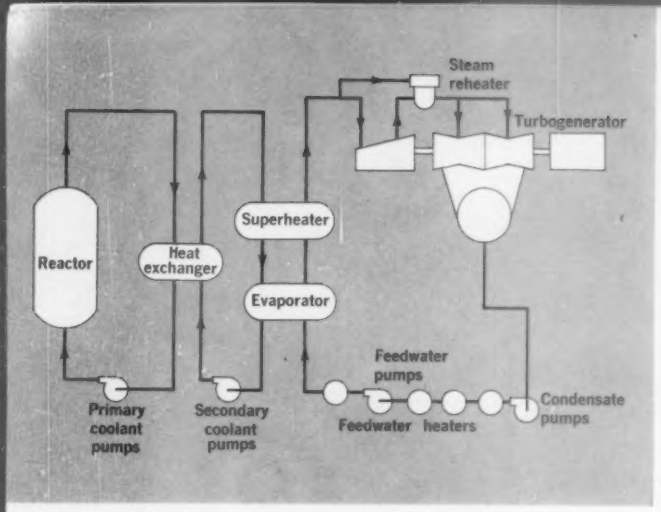
Two-phase mixtures—we are ignorant about carryover, carryunder, pressure drop, relative velocity, and stability of flowing two-phase mixtures.

Water chemistry investigations of "crud" formation on heat-transfer surfaces are needed as well as work on systems to remove impurities from water at high temperature (which could replace present low-temperature ion-exchangers).

REACTOR CONSTRUCTION

Existing or Scheduled	Date Critical
EBWR (5 Mwe) will soon check high-power density stability at 100 Mw(th)	'57
Vallecitos BWR (5 Mwe)	'57
Dresden Plant (80 Mwe)	'59
RWE Reactor (15 Mwe) West Germany	'60
Borax V [20 Mw(th)] will provide nuclear superheat data	'61
Elk River Plant (16 Mwe) will evaluate thorium-uranium oxide fuels and the intermediate heat-exchanger cycle	'61
Sioux Falls Plant (62 Mwe) will incorporate first nuclear superheater in U. S.	'62
SENN Plant (150 Mwe) Italy	'62
Suisatom (15 Mwe) Switzerland	'62
JAERI (12.5 Mwe) Japan	'62
Humboldt Bay (48 Mwe)	'62
High-Power-Density Prototype (50–75 Mwe) will operate at average power density of 60 kw/liter	'63
BONUS (16 Mwe) (Puerto Rico) will evaluate integral s.h. for small reactor	'63
Simplified Prototype (50 Mwe) will prove out lower cost design	'64

AEC's Suggested Program	Date Initiate
Small Prototype (20–30 Mwe) if need exists	'63–64
Integral Superheater Prototype (100 Mwe) if superheat looks good	'63



Fast-Breeder Reactor

The Commission regards liquid-metal-cooled fast reactors as "long-range in nature" but expects research and development to yield significant results in the late 1960's. Existing programs are listed in the box below. These programs will also benefit from Pratt & Whitney's work for the Aircraft Nuclear Propulsion program (P & W plans to build an experimental intermediate-spectrum reactor with liquid-metal cooling), and from Atomics International's work on the SNAP reactors (small, sodium-cooled, high-temperature, fast-reactor Systems for Nuclear Auxiliary Power in space applications). Overseas, the U. K. has its experimental Dounreay reactor in operation and is planning a large fast-breeder plant; the French are considering a 10-Mw(th) advanced design to use Pu fuel.

Key Problems for This Concept

Fuel-cycle development. Investigation must continue on a variety of fuels such as plutonium and uranium oxides, in cermet and ceramic combinations and metal alloys and claddings compatible with these materials. Burnup studies of metal alloys such as fissium (which have high breeding potential) should also continue. The work on a closed, low-decontamination-factor, fuel-reprocessing cycle now under way in the EBR-2 program has led to semiremote fuel-fabrication methods. Methods that give an even higher decontamination factor could reduce the refabrication cost still further.

Fuel-cycle economics. How is power cost affected by:

- Fueling with recycle Pu
- Fuel value of Pu
- Variation in fuel prices
- Use of Th in the blanket
- Chemical composition of fuel
- Alternative fuel-reprocessing techniques

Parametric studies are needed to show how the physics variables—critical mass, breeding ratio and reactivity coefficients—depend on such parameters as neutron spectrum; core and blanket geometry; fuel, coolant and structure compositions; voids and diluents.

Alternative concepts whose merits should be evaluated include:

- The "paste" fuel concept (promises lower fuel-cycle costs)
- Coupled fast-thermal system (improved breeding and safety)
- Direct versus indirect heat-transfer cycles (coolants: sodium, lead, phosphorus or mercury-sodium)
- "Leaky" fuel elements (no fission-gas containment problems and cheaper fabrication)
- Mobile blanket (uniform exposure of the blanket)
- Latticed core with discrete flow channels (refueling and monitoring of individual tubes plus improved safety)
- Blanket thermalization (improvements in control and economics)

Physics investigations of many types are needed; this is particularly true for Pu-fueled systems. Among the topics: reactivity-coefficient variations with temperature; transient effects of power changes; stability under flow changes; improved neutron-flux spectrum measurements; effects of delayed neutrons; better fast-neutron cross sections for plutonium isotopes.

Heat transfer and fluid flow for two-phase sodium flow needs to be investigated. A particular problem is flow distribution in unusual geometries.

Component and systems development. Beyond the problems mentioned under "components development" for sodium-graphite reactors (p. 78), mass transport of carbon by the coolant is of concern. Information is lacking about irradiation effects on stainless steels exposed to a fast-neutron dose of 10^{24}nvt; more efficient and rapid fuel recycle schemes would also help.

Coolant chemistry areas of interest include improved sampling techniques, impurity-removal methods, the effects of impurities in the coolant on structural materials at high temperatures and blanket-gas solubility in sodium.

Instrumentation. New and improved instruments will be required for both the development programs and the full-scale plants.

Safety problems center about (1) prevention of gross core meltdown and (2) predicting the consequences of a meltdown. The first will require extensive operation of test reactors using pile oscillator techniques. The second will involve calculations and experiments in chemical kinetics and final tests in the Transient Reactor Test Facility.

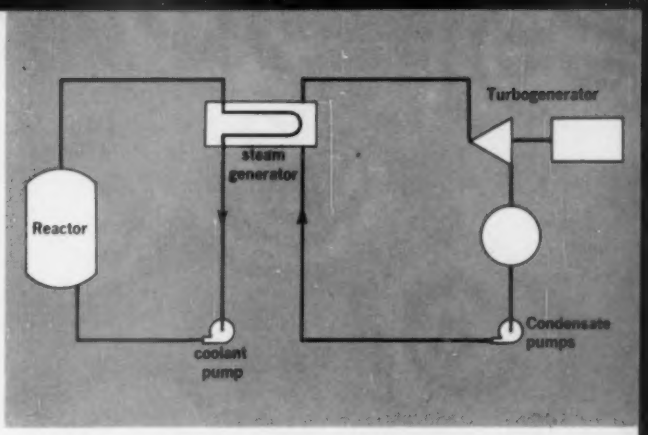
REACTOR CONSTRUCTION

Existing or Scheduled	Date Critical
Experimental Breeder Reactor—I [1 Mw(th)] will begin operation on a Pu cermet core after the current safety experiments	'51
Experimental Breeder Reactor—II (20 Mwe) will incorporate on-site pyrometallurgical fuel processing	'60
Enrico Fermi Plant (94 Mwe) will provide information about U-Mo fuel, in-core fuel rotation, fuel processing, core physics and over-all plant performance	'60

AEC's Suggested Program	Date Initiate
Prototype (100 Mwe) could include features such as a mobile blanket, paste fuel, PuO_2 fuel and higher steam conditions	'63

Aqueous Homogeneous Reactor

Technical feasibility remains to be established for the aqueous homogeneous system and it is not yet clear that the advantages of fuel cycle and breeding potential will be able to outweigh the fuel and maintenance problems and the operating temperature limitations. However, the Commission feels that, because of the unique advantages of the concept and the fact that this is the only large effort on fluid-fuel systems, continued research and development is justified on a long-range basis. If the results with HRE-2 are favorable, the next step will be HRE-3.



Key Problems for This Concept

Alternative concepts. The liquid-metal-fuel and fused-salt concepts are being studied as alternative approaches to the development of a successful thorium breeder; however, no systematic evaluation study has been made of all possible reactor types which might be successful thermal breeders.

Uranyl-sulfate-solutions data needed includes:

- *Heterogeneous equilibrium studies* should be carried to completion to determine the solution limits for the five component system UO_3-CuO-NiO-SO_3-D_2O, the compositions of liquid and solid phases which exist beyond these limits and the phase relationships of the several three and four component systems that are related to the five component system. Also of interest is the solubility of fission products in fuel and their effect on the phase relationships.
- *Reactions in fuel solutions* not completely understood include: peroxide decomposition rates and the effects of catalysts on these rates, the rates at which solutes oxidize and reduce one another and the factors affecting precipitation of fuel constituents. Methods must be developed to remove solids and control deposition of uranium on metal surfaces or adsorption of uranium by corrosion films or corrosion products in suspension.
- *Radiation chemistry tests* on dilute solutions at high power densities (the conditions for large power reactors) to demonstrate the adequacy of recombination and peroxide decomposition reactions and to check for radiation induced instabilities that would not be observed in short experiments with concentrated solutions at high power density or dilute solutions at low power density.

Thoria slurries need these gaps filled in:

- *Surface chemistry studies* of the sorptive or ion exchange properties of representative thoria preparations, the bonding between thoria and adsorbed materials, degree of dispersion of the thoria particles or strength of flocs as indicated by settling characteristics.
- *Caking studies* to find methods to prevent caking and to remove and disperse cakes formed in reactor equipment.
- *Engineering properties* such as the various factors affecting the yield stress and coefficient of rigidity of slurries and investigations of settling and resuspension of slurry in piping.
- *Recombination catalyst* to recombine gases produced in the blanket of a breeder reactor. Preparation methods are needed to provide a catalyst of satisfactory activity and reproducible results. Molybdenum oxide, palladium and platinum have shown promise. Eventually effects of fission products, corrosion products, uranium concentration, thermal gradients and long-term hydrothermal treatment on catalyst activity should receive systematic study.
- *Radiation stability*—although short irradiations have revealed no effects, attrition of the particles and other radiation effects could cause changes in the physical behavior and the usefulness of the slurries.

Corrosion in Reactor Circulating Systems

- *Uranyl sulfate solutions* have no corrosion problem unless acidities higher than those in HRE-2 fuel prove necessary for fuel stability.
- *Slurry fuels* are now being checked for the effect of particle size, shape and concentration and slurry velocity on erosion of a variety of materials in acid, neutral, and alkaline slurries and with deuterium, oxygen and stoichiometric gas overpressures. Conditions for stress corrosion cracking in slurry systems must be established to evaluate the use of austenitic stainless steels.
- *Core- and blanket-material* studies should be started to examine processes and kinetics of corrosion of zirconium alloys and formation and attrition of zirconium-oxide films on the alloys.

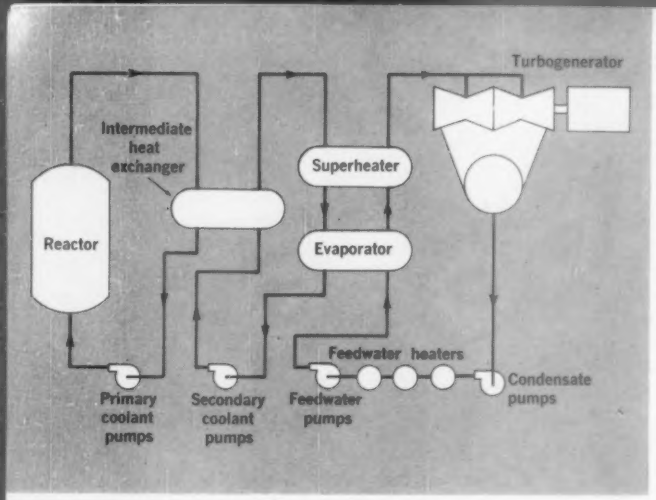
Metallurgy assignments include: further development of Zircaloy-2 manufacturing procedure and the development of zirconium-niobium alloys with ternary or quaternary additions of elements such as palladium, molybdenum, and copper to improve the fabricability. The mechanical properties of zirconium alloys must be better known to design large vessels.

Fuel manufacturing and processing development should aim at better equipment, more economical processes, an improved thorium oxide slurry and facilities for recycling fuel for reactors past HRE-3.

REACTOR CONSTRUCTION

Existing or Scheduled	Date Critical
Homogeneous Reactor Experiment-2 [6 Mw(th)] will continue to investigate fuel stability, remote maintenance and other system problems	'57

AEC's Suggested Program	Date Initiate
Homogeneous Reactor Experiment-3 [5–10 Mw(th)], with uranyl sulfate fuel and a thoria slurry blanket, would check out the two-region power-reactor concept in small scale	'61
Prototype Plant (50 Mwe) would depend on success of HRE-3	late '60's



Sodium-Graphite Reactor

The present complexity and high cost of the sodium-cooled graphite-moderated reactor system and the lack of a high-temperature long-life fuel element for it make an economic debut at an early date unlikely. Operating experience on graphite-moderated reactors has been limited to the Sodium Reactor Experiment but the concept has been able to draw on the sodium experience of the Navy's Seawolf program and the fast-breeder program. Since sodium-cooled fast reactors offer most of the same advantages plus breeding as well, the AEC recommends that work on the sodium graphite concept not be expanded until operating results from the Hallam reactor can be evaluated.

Key Problems for This Concept

Fuel development is the most important problem. The fuel must, at a minimum, have a high thermal conductivity and ability to take average exposures of 17,000 Mwd/mt at a surface temperature of 1,200° F and centerline temperature of 1,400° F. Uranium carbide shows good promise (UO_2 thermal conductivity is too poor). The fuel program should be centered around UC fuel with study of other ceramic fuels as a longer-range development program and "backup" for UC.

Cladding material is needed which has high-temperature strength and creep resistance, compatibility with Na, relatively low cross section, reasonable thermal conductivity and availability in thin sections. A few alloys of Zr, such as 1½% Mo or 1½% Al, compare well, so far, with the present stainless-steel cladding for use in Na at 1,200° F. An additional incentive to develop Zr alloys is the problem of solid-state diffusion between U and stainless steel. Other high-temperature materials that should be investigated are niobium, molybdenum and yttrium.

Materials development. The austenitic stainless steels currently used in the SRE core have high-temperature strength, acceptable corrosion rates and known fabrication techniques. However, ferritic-steel alloys promise to be equally good in these respects and would have the advantages of higher thermal conductivity and lower thermal expansion.

High-neutron-economy zirconium alloys similar to those to be developed for the cladding could be used as process tubes in either the calandria or through-tube concepts, once we have learned to join these alloys to either ferritic or stainless steel.

Design-concept comparison is needed to select the best concept among: (1) the "canned moderator" design in which graphite moderator units are individually canned; (2) the "calandria" design in which the graphite is contained in a single large vessel, vertically penetrated by fuel channels; (3) through-tube designs; (4) designs where the graphite is separately cooled to improve neutron economy; (5) the compact "overflow" design in which the entire primary sodium system is inside the reactor tank.

Other studies should determine the possibilities of Th-U^{233}-breeder and epithermal-nonbreeder concepts.

Physics. Analytical and experimental studies are needed on methods of decreasing peak-to-average power ratios, the use of nonuniform fuel distribution, the reactivity worth of fuels such as UC, optimization of moderator-to-fuel ratio and rod worth.

Sodium-components development (1,200° F outlet):

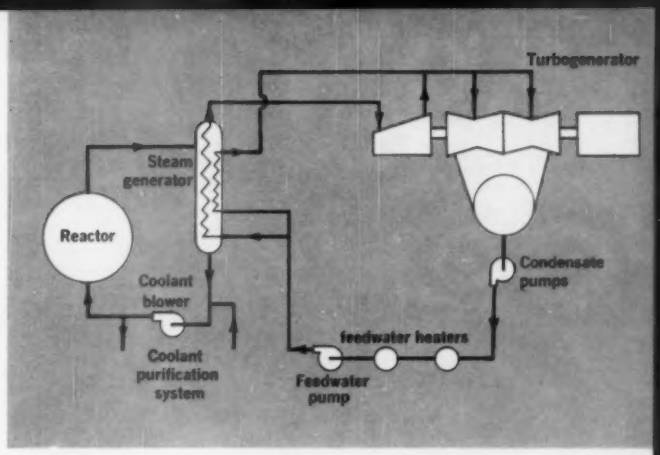
- *Steam generators* probably have the largest potential for improvement of any single out-of-core component. Cost of the present design (double-walled tubes containing a monitoring fluid) might be cut through utilization of (a) high-strength ferritic steel, (b) header arrangements for tube sheets, (c) "once-through" concept (heating, boiling and superheating in same tube) and (d) single-wall tube.
- *Liquid-metal pumps*, both mechanical and electromagnetic, are expensive to maintain because some of their parts are in direct contact with the radioactive sodium. A design in which the magnetic field is rotated mechanically would combine mechanical and electromagnetic features in a way that would make maintenance easier.
- *Valves.* The stop valves developed so far cost $3,000 per inch of valve opening. An experimental investigation of other valve types—freeze-seal, ball-disk and disk-gate types—could lead to reductions in this cost.
- *Intermediate heat exchangers* should be reduced in cost through investigations of high-strength ferritic steel and special configuration for the "overflow" core design.

REACTOR CONSTRUCTION

Existing or Scheduled	Date Critical
Sodium Reactor Experiment (6 Mwe) will test advanced fuels, such as UC, in support of the Hallam plant. Eventually SRE may be converted to high-temperature-fuel test facility or advanced experimental reactor	'56
Hallam Plant (75 Mwe) will start with U-Mo fuel and later switch to UC	'62
AEC's Suggested Program	**Date Initiate**
Advanced Prototype (75 Mwe), contingent on Hallam results	'63

Gas-Cooled Reactor

The Commission is encouraging two versions of the concept: the Experimental Gas-Cooled Reactor, under construction at Oak Ridge National Lab, and the High Temperature Gas-Cooled Reactor, to be built at Peach Bottom, Pa. EGCR has a heterogeneous core with slightly enriched stainless-steel-clad fuel. HTGR has a homogeneous core of fully enriched UC and ThC dispersed in graphite and clad with graphite. Further reactor construction will await the operating results from these two projects. Other projects that will contribute are GE's aircraft nuclear propulsion program, the Army's Gas Cooled Reactor Experiment, the maritime program and U. K.'s DRAGON project.



Key Problems for This Concept*

Thermal breeders. We need to determine the worth of gas-cooled thermal breeders, including a comparison of the over-all inventory doubling times available with different kinds of moderators.

Clad vs. unclad fuel. Unclad systems offer lower capital and fuel costs then the clad systems but at the expense of higher operating costs and unevaluated maintenance and "on-line" availability problems. Which system is more economic?

Containment. Properly designed gas-cooled reactors may require no containment. This is because (1) the energy release upon loss of coolants in gas systems is much less than in water systems and (2) the solid moderator acts as a heat sink and limits temperature excursion. Furthermore, it appears possible to design gas-cooled reactors so that no single accident can lead to complete loss of coolant. For what range of specific power and other design parameters is containment unnecessary?

Remote-fuel-handling study would determine equipment requirements for shuffling fuel within the core and removing spent and damaged fuel. To what extent should fuel-handling requirements exert an influence on fuel-element design considerations?

Component evaluation and development. Possible solutions to the piping problems of high-temperature gas systems must be explored, for example concentric vs. separate hot and cold gas pipes. Blowers for circulating the gas coolant are a particularly important component. It is necessary to evaluate the relative merits of different blower types, bearing techniques (including gas bearings), seals and the merits of canned blower systems. The results will serve to delineate paths for further development. Fuel handling equipment and remote maintenance techniques and equipment also require development.

Heat exchangers. Optimization studies are needed to decide between the once-through boiler with single- and dual-pressure reheat cycle, the supercritical boiler, and the Loeffler boiler.

Fuel materials that deserve consideration include U, UO_2, UC-UC_2, the various nitrides and silicides of uranium and cermets which contain U, such as Cr-Al_2O_3-U. The essential aim of this evaluation and the development work to follow is to find a fuel material that will out perform UO_2, the present fuel material choice.

Cladding materials program would consider stainless steel, beryllium, and high-strength alloys in a search for the best cladding for partially enriched and recycle fuel gas-cooled concepts.

Thermal-cycle analysis will select best among direct cycles, indirect cycles and mixed cycles in which a gas turbine is used as a topping device above the indirect-cycle superheater temperature.

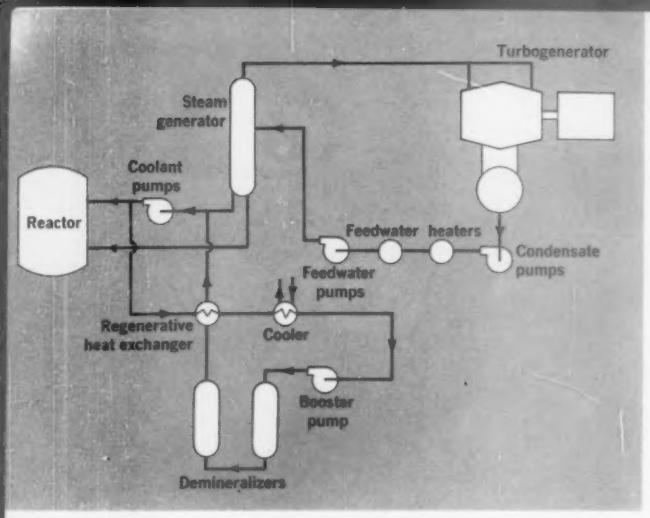
Heat transfer and fluid flow data must be measured and correlated for various fuel-element and coolant-channel geometries; this would include pressure drops, orifice requirements and performance, channel mixing and mechanical stability of elements.

Critical experiments to determine more precise power patterns for core optimization studies, the reactivity lifetime of the fuel and lattice-design numbers. A 100-kw critical facility will be built to operate at full temperature and atmospheric pressure.

REACTOR CONSTRUCTION

Existing or Scheduled	Date Critical
Experimental Gas Cooled Reactor (22 Mwe) under construction at Oak Ridge will furnish firm economic data on gas-cooled-reactor operation and will serve as a flexible facility in which to test advanced fuels, materials and components	'62
Peach Bottom Plant (HTGR) (28.5 Mwe), to be operated by Philadelphia Electric, will pioneer development of impervious graphite high-temperature graphite-dispersion fuel and fission-product trapping methods	'63
AEC's Suggested Program	**Date Initiate**
Advanced Prototype (100 Mwe) would follow successful operation of EGCR and Peach Bottom and would choose between these two approaches	'65

* For EGCR concept only. AEC did not evaluate the HTGR approach at this time (see pages 6 and 72).



Heavy-Water Reactor

We have no operating experience with a D_2O-moderated natural-U-fueled reactor that generates electric power; however we have developed a quite extensive D_2O technology through research and development programs and the operation of the D_2O-moderated production reactors at Savannah River. In addition, negotiations are under way with the Canadians to achieve closer cooperation between the D_2O-reactor programs of the two countries. This will make available to the U. S. experience from the Canadians' concentrated effort on the pressure-tube D_2O concept (see below). These sources of information taken together with reactor construction already scheduled will, the Commission feels, give data to determine by 1966 whether a full-scale plant would be economical in high-cost areas.

Key Problems for This Concept

Pressure-tube development is essential to both the boiling and nonboiling pressure-tube concepts. Necessary investigations include:

- Mechanical, hydraulic and corrosion testing of pressure tubes and joints.
- Irradiation testing of pressure tubes and joints.
- Studies and experiments on the performance of insulated pressure tubes.
- Development of a low-cost high-quality fabrication process for pressure tubes and joints.

Refueling mechanisms, because of the short fuel cycle, must minimize down time and might operate while reactor is at power.

D_2O leakage may prove the most significant problem of the D_2O concept. Methods of reducing and detecting D_2O leakage would involve the development of seals, horizontal joints on components and collection systems. This is especially important if the direct-cycle boiling reactor shows promise.

Evaluation studies are needed to decide between promising variations of the D_2O-moderated concept. The significant comparisons are:

Pressure vessel vs. pressure tube—what are the economic implications of the limitations on reactor size and the effects on reactivity lifetime of a hot vs. cold moderator and the use of different structural materials?

Direct-cycle boiling vs. pressurized—how do the reactivity lifetimes compare and what is the relative leakage of heavy water?

D_2O-cooled vs. gas-cooled or organic-cooled—what is better for a natural-U D_2O-moderated system? How does the D_2O concept compare with a graphite-moderated gas-cooled system?

Reactivity prediction is especially important since reactivity lifetime is a major limitation of the natural uranium fueled D_2O concept. Physics studies for lattices with UO_2-Zr-clad fuel and metallic U-Zr-clad fuel should be made as a function of temperature. These should examine the properties of oxide-fueled lattices with both hot and cold D_2O moderators.

Fuel-element program would decide between metallic-uranium fuel elements and oxide elements. So far metallic fuels offer higher reactivity and lower fabrication cost while oxide has better irradiation stability and corrosion resistance. The program must cover irradiation testing of prototype metallic fuel elements, development of cheaper fuel fabrication methods and experiments to determine corrosion rates and the effects of fuel defects that occur during operation of the reactor.

REACTOR CONSTRUCTION

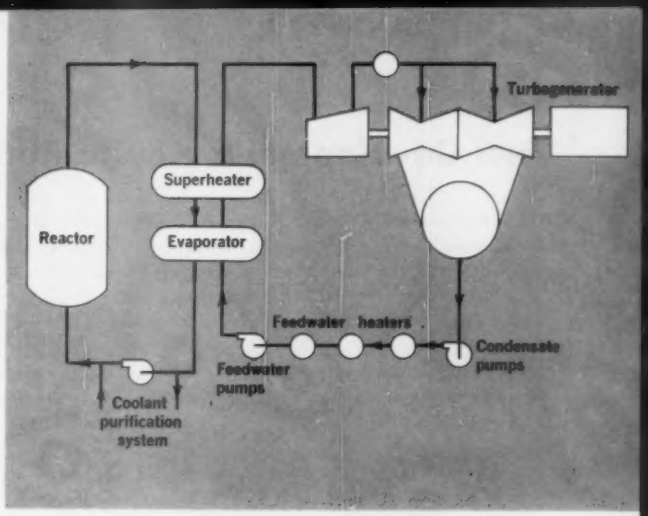
Existing or Scheduled	Date Critical
Halden Reactor (20 Mwe) (Norway)	'59
Pu Recycle Test Reactor [70 Mw(th)], since it is a pressure-tube design with D_2O cooling and moderation, will provide operating experience useful for future application	'60
Heavy-Water Components Test Reactor [61Mw(th)] will irradiate fuel elements and other components of interest to designers	'61
Nuclear Power Demonstration Reactor-2 (20 Mwe) (Canada) will check out UO_2 fuel design and fabrication methods as well as Canadian philosophy of continuous refueling	'61
Carolinas-Virginia Plant (17 Mwe) will be slightly enriched and will serve as U. S. prototype for pressure-tube D_2O plants	'62
Florida Nuclear Power Group's Plant (50 Mwe) is now under evaluation, with the decision to proceed with construction still in abeyance	'63
CANDU (200 Mwe) (Canada) will be world's first large-scale D_2O power reactor	'65

AEC's Suggested Program

No additional projects foreseen

Organic-Cooled Reactor

It is likely, says AEC, that the organic-cooled reactor will be competitive in high-cost areas by the middle '60's and in many other areas later on. The concept is expected to reach this stage with less research and development and fewer experimental and prototype plants than will be required by the other reactor concepts. This will be possible because the system is relatively simple, it has been able to borrow much from water-reactor technology and it has passed with flying colors the developmental hurdles set up so far, which include the operation of Organic Moderated Reactor Experiment. When the more immediate problems of the organic concept have been solved (see below), the development effort will switch to an investigation of Pu recycle and other advanced features for organic systems.



Key Problems for This Concept

Heat transfer is a limit on performance because of the low thermal conductivity of organics. Development work would ascertain whether improved forced convection or nucleate boiling is the best way to increase heat transfer. The former approach would attempt to establish what heat-transfer limits are obtainable with forced convection and would include comparisons of different organics and studies of chemical additives and the formation of residues. The latter would investigate the maximum safe limits of heat transfer for nucleate boiling, the decomposition of the organic and the effect of chemical additives on inhibiting the formation of residues.

Coolant technology requires more experimental attention to:

- *Organic physical properties* such as the density, heat-transfer coefficients, viscosity, flash point, thermal conductivity and specific heat at the temperature and flow conditions of interest.
- *Coolant compatibility* in the reactor environment, including corrosion rates with the structural materials and decomposition rates from radiolytic and pyrolytic processes. Soluble poisons, decomposition-product removal and steam inleakage would also be studied.

Component development that would lead to better performance or cost reductions includes:

- *Control-rod-drive mechanism* development program to determine the mechanism most compatible with an organic-cooled reactor.
- *Shaft seal* program to develop reliable seals for pumps and valve stems in the primary loop.
- *Refueling equipment* program to perfect the best method of fuel handling and relocation of fuel.

Physics studies to evaluate flattening power, the power distribution change with burnup, fuel management, plutonium recycle, xenon oscillation and optimum moderator-fuel ratio are needed, as well as critical experiments to fix lattice parameters, critical loadings, temperature coefficients and control-rod worth.

Fuel-element development, the most critical area for the organic reactor, aims at a long-burnup element with a large heat-transfer surface area. Uranium-molybdenum metal-alloy and UO_2 fuels are presently being developed. The key item is a cladding material with high thermal conductivity, can be easily extruded with fins and is compatible with the coolant up to 900° F. The most promising cladding material so far is a sintered aluminum containing a 6–8% dispersion of Al_2O_3. Zirconium is unsuitable because of a hydriding effect with the organic; stainless steel is too low in thermal conductivity for the heat-transfer-limited organic core.

REACTOR CONSTRUCTION

Existing or Scheduled	Date Critical
Organic Moderated Reactor Experiment [15 Mw(th)] will continue as a fuel element test facility and as a source of information on coolant decomposition	'57
Piqua Plant (11 Mwe) will be of primary importance as a prototype for small plants	'61
Experimental Organic Cooled Reactor [40 Mw(th)] at NRTS will allow an acceleration of testing on alternative fuels, coolants, moderators and operating conditions	'62
Prototype Plant (50–100 Mwe), now out for proposals, will provide data on improved fuels such as UO_2 clad with Al cermet and will serve as a stepping-stone to large scale organic power plants	'64
AEC's Suggested Program	**Date Initiate**
Advanced Prototype Plant (50–100 Mwe), if needed to demonstrate technical improvements that arise as a result of experience with the earlier plants	'65

Fuel Developments Key to Reactor Progress

AEC evaluations of solid-fuel reactor concepts point clearly to the need for fuels that are "better"—both cheaper to fabricate and capable of operating at higher temperatures and burnups. Fuel development during the next 10 years will focus on investigation of material properties, development of fabrication methods, preparation of samples, irradiation under conditions duplicating reactor conditions, evaluation of performance, and evolution of simple configurations and fabrication processes that promise economies in large-scale production.

Both metallic and ceramic fuels are serving in civilian power reactors, but to make improvements, it is essential to learn more of the fundamental mechanisms of property changes—such as the release or retention of fission-product gases—and much additional data are needed on material properties at high temperatures and burnups.

Metallic Fuels

To reduce over-all fuel costs, metal fuels need to be able to serve with peak temperatures over 1,250° F. But since accumulation of fission gas causes metallic uranium, thorium, plutonium, and their alloys to swell excessively at 750–930° F, more basic information is needed on swelling phenomena before limiting conditions can be predicted.

U-base alloys. Except for the costly low-Zr:U alloys, extensive experience in fabricating most U-base fuel alloys is lacking. Alloys most likely to be used in power reactors are high-strength high-temperature alloys such as those of U-Mo and U-Nb, but their relative strength at elevated temperatures presents fabrication problems that must be resolved in the development program. Uranium-fissium and U-10%Mo alloys are being studied vigorously even though the poisoning effect of Mo necessitates increased uranium enrichment. The U-10%Mo alloy appears satisfactory up to 1,100° F and 0.7 a/o burnup; brief data indicate that gross swelling is caused by cycling above 1,100° F.

Generally, their high uranium content makes metal fuels preferred over ceramics for fast reactors. But since the poor heat-transfer characteristics of gas coolants require that fuels operate at particularly high temperatures, all long-range plans for gas-cooled reactors call for ceramic fuels.

Ceramic Fuels

Ceramic fuels generally are susceptible to thermal-stress failure because of their brittleness and low thermal conductivity—thus, except for BeO and graphite semi-homogeneous fuel elements, ceramic fuels require structural support from the cladding. Presently, most clads are of metal, which limits operating temperature and involves high-integrity welding of the cladding. The low thermal conductivity of ceramics tends to limit their use to reactors that do not generate high specific power.

UO_2. Uranium dioxide is used more than any other ceramic as fuel in water-cooled civilian power reactors. Future fabrication development will be limited to investigations offering large cost cuts or to new and novel methods, such as hot-swaging or vibratory compaction. For design purposes, statistical data are needed on thermal conductivity under irradiation, high-temperature properties (such as plasticity), ultimate burnup achievable, the mechanism of central-void formation, frequency of clad failures, rate and mechanism of gas diffusion as a function of density, burnup, temperature, and time, effects of U:O ratio on fabrication and properties (such as water corrosion, radiation damage, and thermal conductivity), and the possibility of vapor-phase or hydrothermal transport of UO_2, which might be a problem in cases of extensive cladding failures.

PuO_2. Experience with plutonium dioxide is very limited; facilities are becoming available now that suitably contain it during processing and fabrication.

UC. Uranium monocarbide reacts with water, but is compatible with sodium. This, together with its high thermal conductivity, suits it for high-temperature high-specific-power reactors cooled by sodium. Present casting methods do not offer promise of rapid development for low-cost large-scale production. Lab-scale facilities and studies of alternative methods of producing dense UC are imminent. Statistical and basic data are needed on the rate of volume change during irradiation, fission-gas release, burnup and temperature limits, effects of fabrication methods and compositional variations, and reaction with cladding materials at high temperatures.

For fast breeders, PuC and compositions in the UC-PuC system appear promising. Development and sample preparation will be stepped up and irradiation data obtained and evaluated.

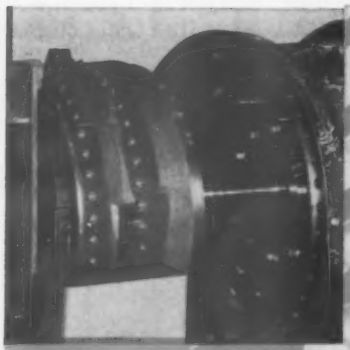
Other ceramics. Except for UC, research on non-oxide ceramic fuel materials mainly involves laboratory-scale materials preparation and evaluation of physical and mechanical properties. Nitrides, sulphides, phosphides, and some of the aluminides are being studied.

Fueled graphite has great potential for gas-cooled reactors. Research problems to receive attention include the development of more efficient ways of using metal jackets and impermeable ceramic claddings, and study of the irradiation behavior of uncoated and coated fueled graphite and of graphite containing dispersed and coated uranium compounds.

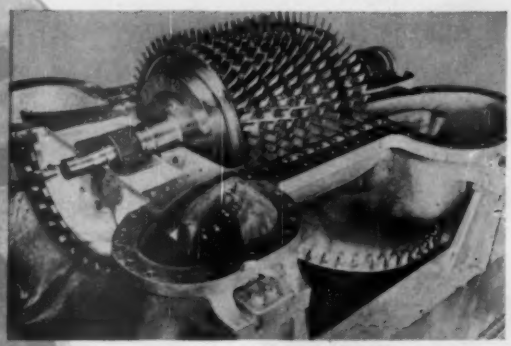
Cladding and Bonding

All known magnesium alloys have unsatisfactory high-temperature properties. The costly-to-fabricate zirconium alloys appear to have limited potential for use in future high-temperature water or sodium reactors. Because of the problem of eutectic melting of stainless steel with U alloys at localized hot spots of about 1,350° F, greater efforts will be made to develop alternative high-strength clads to replace stainless steel; this is particularly important for sodium-cooled reactors. The fabrication, irradiation behavior, and long-time corrosion resistance of Fe-Al alloys will be investigated since they may substitute for stainless steel in water-, organic-, and sodium-cooled reactors below 1,000–1,200° F. New aluminum alloys offer economy in 600–650° F water reactors and in 800° F organic reactors if structural strength is not important, but more data is needed on fabrication, end closures, the effect of welding on metal properties, and long-time inpile corrosion.

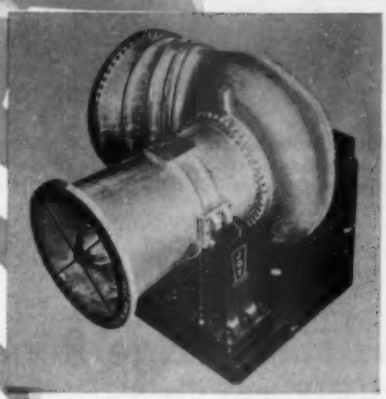
Because of the need for assurance of high-integrity cladding and bonding, it is essential to achieve better basic understanding of nondestructive testing techniques.



Assembly of Barrel Compressor.



15,000 hp multi-stage axial flow compressor.



6,000 hp axial flow compressor with 1100°F inlet temperature.

JOY OFFERS UNIQUE CAPABILITIES IN GAS CIRCULATOR DESIGN

Compressing gases at the high temperatures and pressures required for gas-cooled reactor loops is routine to Joy engineers. In working with the nuclear power industry, Joy has provided compressors capable of handling inlet temperatures to 1100° F, considerably above design temperatures now used in primary loops. Double-case construction and metallurgical design know-how have solved the many difficult structural and thermal problems.

Full consideration has been given to the problems relating to controls and aerodynamic stability of reactor cooling loops using circulators in parallel. A unique line of centrifugal compressors has been developed with extremely desirable characteristics. Increasing pressure with decreasing volume is available to zero flow, with no flow instability or surge.

In addition, Joy is the exclusive distributor in the United States for De Havilland Gas Circulators for radioactive auxiliary and test circuits. These circulators are leak-proof and contamination-free. An outstanding feature of their design is the use of gas bearings.

For complete details on Joy gas circulating compressors, write for Bulletin 1282-92.

AIR MOVING EQUIPMENT FOR ALL INDUSTRY

JOY

Joy Manufacturing Company
Oliver Building, Pittsburgh 22, Pa.

In Canada: Joy Manufacturing Company (Canada) Limited, Galt, Ontario

FIG. 1. FILM BADGE includes perforated lead insert that, when exposed to X-rays, records badge number on film in binary code for subsequent reading

FIG. 2. AUTOMATIC FILM READER. Densitometer and badge-identifying head is in foreground. Beta and gamma dose and badge number are displayed digitally and punched onto IBM cards with auxiliary unit

Automatic Film-Badge Reader

By MACK WILHELMSEN, DeRAY PARKER, ROBERT W. COULTER and PAUL R. BOREN
Health and Safety Div., U. S. Atomic Energy Commission, Idaho Falls, Idaho

Several thousand film badges are processed each week at the National Reactor Testing Station. To handle this volume and prepare the permanent records required, a highly automated film-reading and data-recording system has been developed. Performance studies have shown that the reader is linear and has a reproducibility of about 97%. We estimate that the system could be duplicated for about $10,000.

The Film Badge

A Hanford-type film badge (Fig. 1) was modified slightly to provide mounting space for a lead identification insert. The film packet is positioned by a retaining compartment of the slide. Half of the film is used for radiation-exposure determinations as defined by open-window, cadmium-shielded, silver-shielded or aluminum-shielded areas. The other half is used for a binary identification code which is X-rayed onto the film through the perforated lead insert, which is cemented permanently onto the badge slide.

Each person requiring a badge is given a permanent identification number containing six digits, the first two of which designate an area location. A radix of eight was chosen for the number system in order that the binary conversion could be contained in six groups of three binary bits each. Conventional digits, 0 through 7, are used; there are no 8's or 9's in the system. Thus an assigned number can be read conventionally. The 18 perforations, arranged in two rows of nine each, provide 262,144 separate badge number arrangements or 4,096 arrangements for each of 64 different areas.

An electromechanical device converts an assigned six-digit number into binary form and punches 0.140-in.-dia holes in the 18-gage lead shield accordingly.

Preprocessing

At the end of the exposure period, individual badges are returned to racks located at the gatehouse of each respective area. Badge racks are carried into a walk-in delivery van. Here badges are stacked between sloping guide rails that allow one at a time to drop onto a conveyor belt. Each badge, in turn, passes under a G-M counter and alarm system designed to stop the conveyor should a badge be contaminated (about one per 100,000 is). If contaminated, the badge is removed from the conveyor for special handling and decontamination.

"Clean" badges move beyond the G-M detector and are accurately guided over a collimated X-ray port. When in position, each badge actuates a

WRONG WAY TO LIGHT A NUCLEAR REACTOR

Initiating a nuclear reactor fuel fabrication program with disregard of the resulting cold scrap is like burning money! Davison, as the largest reprocessor of uranium cold scrap, quickly converts useless, but expensive, uranium scrap into AEC credit amounting to thousands of dollars. If you operate a reactor or fabricate fuel for a nuclear reactor, you gain a distinct advantage by consulting Davison on the economical collection, segregation and storage of uranium scrap before it is created. Contact Davison today.

DEPARTMENT A-304

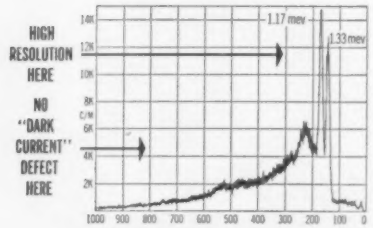
W.R. GRACE & CO.

DAVISON CHEMICAL DIVISION

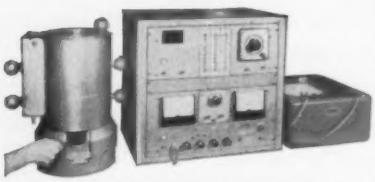
ERWIN, TENNESSEE

This NMC Gamma Spectrometer Eliminates "Dark Current" Defect

Combines Better Resolution With Greater Precision Over Wider Range Than Any Other System At Any Price

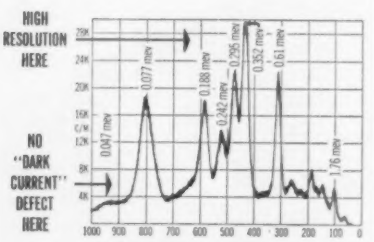


Actual spectrogram of Cobalt-60 made with a GSS-1. Window No. 3. Time constant: 2 sec.



A complete gamma spectrometer system NMC model GSS-1 ($4,180 fob, Indianapolis)

This greatly simplified system features regulated high voltage supply as part of the counting ratemeter auto-scan system . . . all-transistorized probe amplifier and spectrometer circuits . . . and solid or well-type crystal. These points and the actual spectrograms shown here tell only part of the story. For full details, write or phone collect.



Actual spectrogram of Radium made with a GSS-1. Four runs over a period of 20 hours with no adjustment of instrument between runs, demonstrating utmost stability. Range: 30,000 C/M. Time constant: 3 sec.

Booth 634
Atomic
Exposition

NMC

Nuclear Measurements Corp.

2460 N. Arlington Ave. • *Phone:* LIberty 6-2415
INDIANAPOLIS 18, INDIANA

International Office: 13 E. 40th Street, New York 16, N. Y.

INSTRUMENTATION AND MEASUREMENTS

This article starts on page 84

microswitch and the X-ray unit is energized. The collimated X-ray beam exposes only the number area of the film to produce the binary-coded latent image. Badges can be scanned and X-rayed at the rate of about 35/min with this unit.

Each badge is then unlocked with a magnetic badge opener, the film packet is removed, and each badge is reloaded and returned to the gatehouse racks for the next exposure period.

Darkroom Processing

The film packets are taken to a central darkroom. Each film is unwrapped by hand and loaded into a special tray used both for development and reading. The tray is a dual unit, so designed to accommodate 50 each of both the sensitive and insensitive film contained in the film packet. A film-loader is used to facilitate the loading of trays in the darkroom. As each slot is filled, the tray is advanced one interval by the loader so that the next film can be guided into position.

As many as 20 loaded trays can be stacked into a stainless-steel rack for immersion into the 15-gal processing tanks. Care must be taken when immersing or removing film trays from solutions; otherwise surface tension of the liquids can pull two film sheets together and leave them bonded or warped after the drying process.

Automatic Film Reader

The automatic film reader (Fig. 2) consists of a densitometer head, a badge-number matrix, a film-density computer, two digital voltmeters (one for beta dose and one for gamma), a master control panel and associated power supplies. Pertinent information, collected and processed by the film reader, is fed to a modified Model 026 IBM card punch that produces a permanent punched record.

The film tray is placed into a spring-loaded tray guide on the film changer table and advanced until the first film to be read is indexed beneath the film slot in the densitometer head assembly, shown opened in Fig. 3. At this point, a spring-loaded microswitch pawl drops into a ratchet cut into the tray bottom, and film-tray advancement stops. An electric clutch energized by this action moves a reciprocating arm upward through the open bottom of the tray. Steel tension fingers grasp the film and

FIG. 3. DOSIMETER HEAD opens in plane of film for servicing. Film is being raised to position in which badge code number and beta and gamma dose can be read

slide it into reading position within the indexing block. This block was machined of Teflon—its smooth, soft and long-wearing surface does not scratch emulsion from the film.

On the opposite side of the film and looking toward the light source, there are eighteen 0.07-in.-dia photodiodes (Sylvania IN77B) and two ¾-in.-dia photomultipliers (Dumont K1303) used as light-sensing devices. The photodiodes are positioned to correspond to and "read" the binary code spots on the film. The photomultipliers are positioned to look at the open window (beta) and cadmium-shielded (gamma) areas of the film, respectively.

All photodiodes feed their information simultaneously into a relay-switching matrix that converts the 18-bit code into six corresponding numbers from 0 to 7. A six-digit visual readout displays the film identification number, and appropriate IBM punch magnets are actuated as the proper card column within the badge number field is programmed into the punch position.

Dose Determination

Beta- and gamma-dose values, associated with the densities of two designated film areas, are determined by the response of the two corresponding photomultiplier tubes acting through associated logarithmic circuitry. One film area, having been shielded during exposure by 950 mg/cm² of cadmium is defined as the "gamma" field. The other area, having been shielded by the plastic badge and film wrapping only, is defined as the "beta" or open-window field.

The two photomultiplier output volt-

Size for Size...
New ASCO Midget 3 Way
Solenoid Valve
provides

UNMATCHED FAST RETURN
UNMATCHED FAST RETURN
UNMATCHED FAST RETURN
UNMATCHED FAST RETURN

Of Cylinders and Diaphragms

INTEGRAL OVERSIZE ORIFICE SPEEDS EXHAUST CYCLE . . . ELIMINATES SEPARATE QUICK VENT VALVE.

New 3 way Bulletin 8317 with full ¼" diameter exhaust orifice provides quick venting of pressure from cylinders and diaphragms . . . assures the fastest cylinder or diaphragm return of any valve its size. It takes the place of larger, more expensive valves . . . eliminates need for connecting a separate quick vent valve in the circuit to speed up the exhaust cycle.

This ASCO valve has only 2 moving parts, mounts in any position. Available in normally open, normally closed and universal construction . . . with general purpose, explosion proof or watertight solenoid enclosures in ¼" pipe size . . . for pressures to 160 p.s.i. . . . for water to 100°F, air, gases and light hydraulic oil to 180°F.

The Bulletin 8317 Valve is available immediately from stock. **WRITE** for catalog literature and for the new ASCO Stock List & Selection Guide listing the world's largest stock of solenoid valves for immediate delivery.

ASCO Valves

Automatic Switch Co. 52-M HANOVER RD., FLORHAM PARK, N. J., FRONTIER 7-4600

AUTOMATIC TRANSFER SWITCHES • SOLENOID VALVES • ELECTROMAGNETIC CONTROL

ASCO

ANTON

Neutron and Gamma Detectors for Naval Reactors

- **Meet requirements of Mil-Std-167 and Mil-S-901 for vibration and shock**
- **Advanced, high temperature, watertight detectors available**
- **Delivery from continuous production at economical cost**

SEND FOR FREE DATA NOW!

Anton 818/7087 Multi-element High Sensitivity Neutron Detector

Anton 807/6377 Electrically Compensated Ionization Chamber

Anton 813/6937 Uncompensated Ionization Chamber

Anton 812/6375 Duo-Range Fission Chamber

Anton 805/6307 Neutron Proportional Counter

Anton Boiler-Leak Gamma Detector

Anton 302/5980 Gamma Detector

ANTON ELECTRONIC LABORATORIES, INC., 1226 Flushing Avenue, Brooklyn 37, N. Y.

☐ Send me FREE Neutron Detector Catalog
☐ Send me FREE Alpha, Beta, Gamma Detector Catalog

NAME.....

CO. OR INSTIT.....

ADDRESS.....

CITY..... STATE.....

ANTON ELECTRONIC LABORATORIES, INC.

1226 FLUSHING AVE., BROOKLYN 37, N. Y.

This article starts on page 84

ages, proportional to light intensities transmitted through the film, are fed into a simple analog computer, which corrects, by a factor established during instrument calibration, for low-energy gamma rays that do not penetrate the cadmium shield but do affect the open beta area. Finally the gamma output is subtracted from the beta voltage to give the true beta dose.

The system is zeroed and calibrated manually by reading blank and 300-mr-calibration films that have been developed along with the field run.

The beta and gamma output levels from the analog-computer circuit are fed into respective digital voltmeters. Each voltmeter displays a visual read-out of the dosage value and provides contact closures to actuate the proper IBM punch magnets when programmed to do so. Programming is established for the over-all system within the IBM punch unit by affixing a prepunched program card to the program drum. Signals from the punch cause the film reader to respond to the program sequence via a master control unit.

Date, time, repetitive and skip information is automatically punched into the card through the programming system.

Alarm circuits. Special fail-safe circuits react to and indicate the following unnatural conditions:

1. A film has not been X-rayed. This condition results in an unassigned area number 00, which has been wired to stop the operation until released by the operator.

2. Excessive exposure. A maximum exposure level corresponding to 300 mr has been set and the circuit is wired to stop operation above this level. This condition, due to heavy darkening of the film might suggest an area number 77 erroneously. Occurrences of this magnitude are rare and should be handled separately anyway.

3. Film lift fails to return film to tray. A microswitch within the reading head senses this condition and stops the operation.

* * *

The authors are indebted to F. V. Cipperley, Chief of the Personnel Monitoring Branch, for his assistance in defining the needs of the Film Dosimetry Program and to Alan Harbertson for technical advice on X-ray equipment.

Complete drawings of mechanical assemblies and electronic circuits can be obtained from the authors upon request.

Focal Point for Nuclear Science and Engineering

The John Jay Hopkins Laboratory for Pure and Applied Science is the focal point of General Dynamics' General Atomic Division in San Diego, California . . . a modern center where strong engineering and developmental activities are combined with broad basic theoretical and experimental research . . . an ideal environment for productive efforts in the fields of nuclear engineering and science.

Here, advanced work is underway on the High Temperature Gas-cooled Reactor (HTGR), which promises to be a major short cut to the nation's goal of economic nuclear power. The prototype HTGR plant will be completed in 1963 for Philadelphia Electric Company and High Temperature Reactor Development Associates, Inc.

Here, engineers and scientists work in a creative atmosphere in other advanced activities, including the MGCR gas-cooled reactor and closed-cycle gas turbine system for merchant ship propulsion . . . TRIGA reactors for training, research, and isotope production, which are now being installed on five continents . . . small nuclear power systems . . . test reactors . . . nuclear power for space vehicles . . . thermoelectricity . . . controlled thermonuclear reactions.

Rapid expansion of these programs has created openings, including senior positions, for experienced engineers and scientists who seek a high degree of individual responsibility together with unusual opportunities to demonstrate their initiative and ability. In engineering, for example, immediate openings now exist for nuclear engineers to work on the following programs:

- Reactor core design and thermal analyses.
- Reactor design neutronic calculations.
- Analyses of reactor and system controls.
- Evaluation of economics associated with reactor core design.
- Operation and analysis of critical experiments and applications of results to reactor design problems.

In addition to positions for Nuclear Engineers, openings also exist for qualified Chemical Engineers, Metallurgists, Mathematicians-Programmers, and Experimental and Theoretical Physicists. Please address your letter of inquiry to Manager of Personnel, General Atomic, 11000 John Jay Hopkins Drive, San Diego 12, California.

GENERAL DYNAMICS

GENERAL ATOMIC DIVISION

8692 and 8693 TEMPERATURE POTENTIOMETERS

Choose from 24 temperature and millivolt ranges when you order your new 8692 Single-Range or 8693 Double-Range Portable Temperature Potentiometers. Unusually flexible for measuring temperatures with thermocouples in plant or laboratory, these indicators provide a two-turn slidewire with a big, easy-to-read 27½" scale, calibrated in 400 or more div. For information on ranges and parts for range changes, get Data Sheet ND42-33(1A).

List No. — *8692 Single-Range Portable Temperature Potentiometer (8693 similar but has two ranges).*

Range—*Complete list in Data Sheet ND42-33(1A); ask for your copy.*

Limit of Error—*±0.2% of range.*

Maximum External Resistance—*50 Ω.*

Reference Junction Compensation—*Automatic on all temp. ranges.*

Function Switch — *Three-position switch provides following internal connections: (1)* "OUTPUT" *(2)* "STANDARDIZE" *(3)* "MEASURE."

Galvanometer—*Sensitivity: 1.0 μa per scale div. Scale: 20 one-mm div.*

Case—*Metal with handle & removable lid, 12-11/32" x 8-20/32" x 7⅜".*

Price—*8692: $270.00. 8693: $330.00 f.o.b. Phila. or North Wales, Pa. (subject to change without notice). Specify Nos. 8692 or 8693 with desired range suffix numbers, obtainable from your nearest L&N Office or 4936 Stenton Ave., Phila. 44, Pa.*

LEEDS NORTHRUP
Instruments Automatic Controls • Furnaces

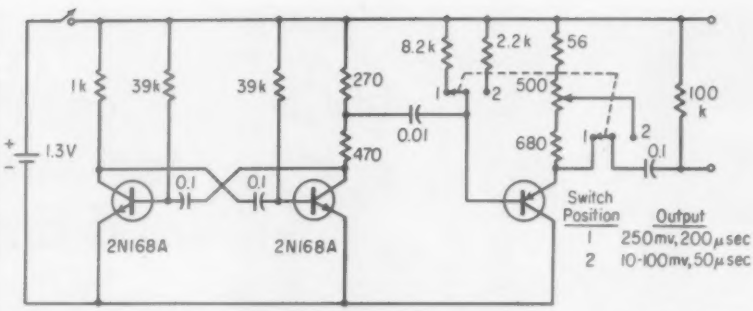


FIG. 1. TRANSISTOR PULSER produces negative pulses like those of G-M and scintillation detectors for testing amplifiers, scalers, counting-rate meters and analyzers

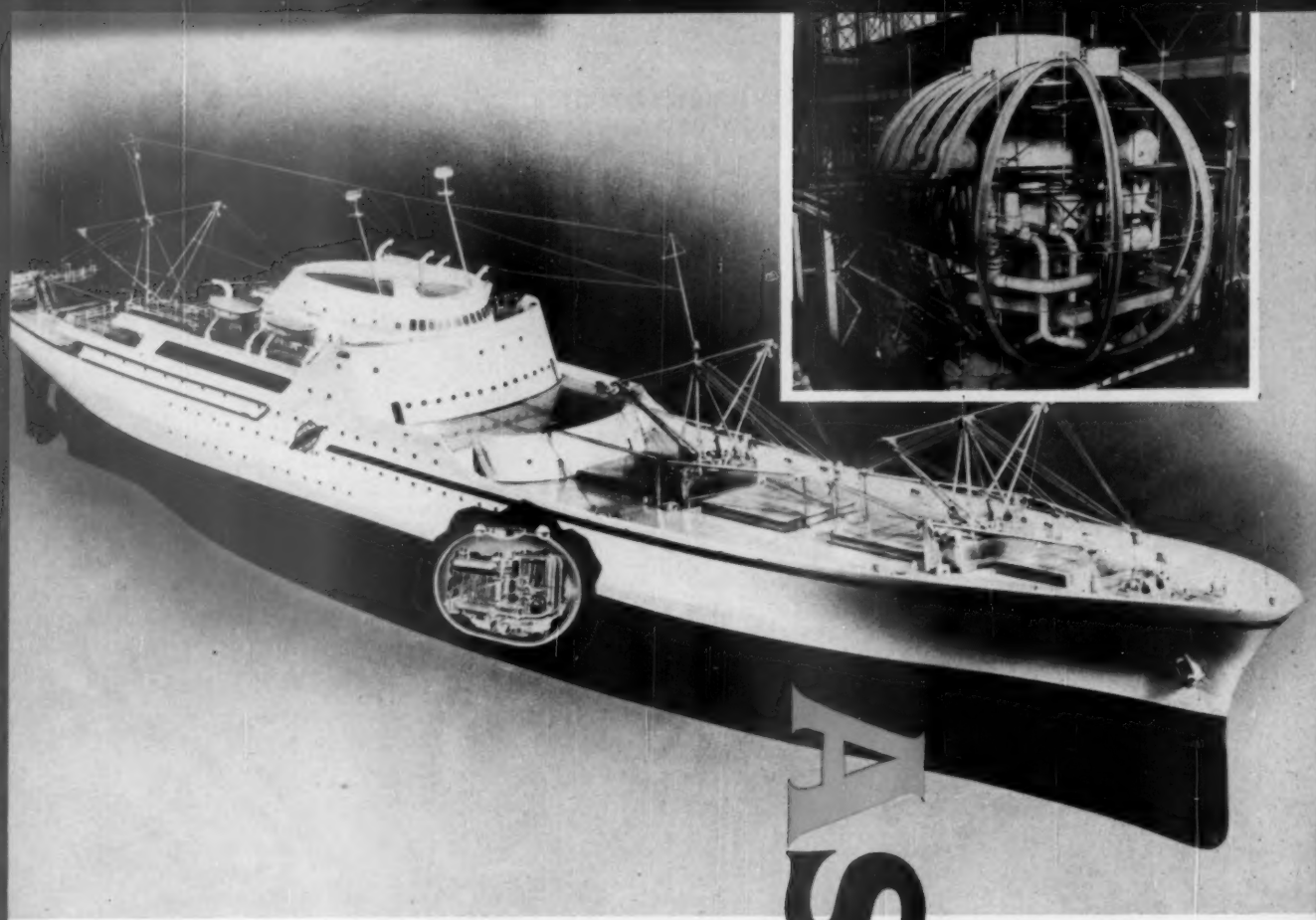
Transistor Pulse Generator

By EDWIN GORDY and GEORGE SIEBER
Roswell Park Memorial Institute, Buffalo, New York

Test pulses are essential for checking amplifiers, scalers, counting-rate meters and pulse-height analyzers associated with G-M and scintillation detectors. We use a small-sized, self-contained, battery-operated pulser with unusual stability in frequency and amplitude. The circuit has three transistors, two in a multivibrator and one in an emitter follower isolation stage.

Our generator furnishes two kinds of pulses: in Position 1 of the selector switch (Fig. 1) the output is a 150-μsec 250-mv negative pulse simulating the output of a G-M tube; in Position 2, the output is a 50-μsec negative pulse with an adjustable amplitude of 10–100 millivolts. This output is like the pulse from a NaI(Tl) crystal-photomultiplier combination. Amplitude is

FIG. 2. KEY SHOWS SIZE of battery-operated, self-contained unit



The experienced and complete shielding guidance you need:

FEDERATED LEAD FOR RADIATION PROTECTION

Federated can help you design structures or devices to house, handle, or transport radioactive materials. Federated has designed Interlocking Lead Bricks* and other unique lead protective products. They include convenient lead containers, one pound to 10 ton casks, and larger to your precise specifications. Also available are cast, rolled, and extruded lead sheets, plates, and piping. Asarco's Central Research Laboratory offers a wealth of information and shielding guidance. Write or call Federated Metals Division, American Smelting and Refining Company, 120 Broadway, New York 5, REctor 2-9500, or call your nearest Federated sales office.

*Patent Pending

ASARCO

AMERICAN SMELTING AND REFINING COMPANY

FEDERATED METALS DIVISION

Where to call for information:

ALTON, ILLINOIS
Alton: Howard 5-2511
St. Louis: Jackson 4-4040

BALTIMORE, MARYLAND
Orleans 5-2400

BIRMINGHAM, ALA.
Fairfax 2-1802

BOSTON 16, MASS.
Liberty 2-0797

CHICAGO, ILL. (WHITING)
Chicago: Essex 5-5000
Whiting: Whiting 826

CINCINNATI, OHIO
Cherry 1-1678

CLEVELAND, OHIO
Prospect 1-2175

DALLAS, TEXAS
Adams 5-5034

DETROIT 2, MICHIGAN
Trinity 1-5040

EL PASO, TEXAS
(Asarco Mercantile Co.)
3-1852

HOUSTON 29, TEXAS
Orchard 4-7611

LOS ANGELES 23, CALIF.
Angelus 8-4291

MILWAUKEE 10, WIS.
Hilltop 5-7430

MINNEAPOLIS, MINN.
Tuxedo 1-4109

NEWARK, NEW JERSEY
Newark: Mitchell 3-0500
New York: Digby 4-9460

PHILADELPHIA 3, PENNA.
Locust 7-5129

PITTSBURGH 24, PENNA.
Museum 2-2410

PORTLAND 9, OREGON
Capitol 7-1404

ROCHESTER 4, NEW YORK
Locust 5250

ST. LOUIS, MISSOURI
Jackson 4-4040

SALT LAKE CITY 1, UTAH
Empire 4-3601

SAN FRANCISCO 24, CALIF.
Atwater 2-3340

SEATTLE 4, WASHINGTON
Main 3-7160

WHITING, IND. (CHICAGO)
Whiting: Whiting 826
Chicago: Essex 5-5000

IN CANADA: Federated Metals Canada, Ltd.
Toronto, Ont., 1110 Birchmount Rd., Scarborough, Phone: Plymouth 73246

Montreal, P.Q., 1400 Norman St., Lachine, Phone: Melrose 7-3591

Eldorado

DECIMAL SCALERS
FOR THE NUCLEAR PHYSICIST

...and Fast

Eldorado solid state all-electronic scalers count random events at a maximum rate of over one million counts per second. Resolving time is less than 1.0 microsecond. Especially well-suited for accelerator counting room service, these compact instruments weigh just 13 pounds and use ⅓ fewer transistors than comparable models. They can be used wherever the advantages of complete transistorization are important.

Eldorado offers three standard models in the SC-750 series, each with built-in regulated power supply. Two models provide full electronic storage of 10^7 and 10^8 counts. The third has 3 decades of electronic storage and a 4-digit mechanical register. Special versions can be furnished with other counting combinations and provisions for readout to a printer or tape punch.

KEY SPECIFICATIONS

SCALER	
Resolution	Better than 1.0 microsecond
Max. Counting Rate	Greater than 1 megacycle
AMPLIFIER (optional)	
Minimum Input Signal	10 millivolts
Overload Recovery	7 X, 7 microseconds
DISCRIMINATOR TYPE	Integral
RANGE	1 to 11 volts
SIZE	19 x 3¼ x 10½ inches

Eldorado can furnish scalers and counters to fit your specific application. For more details, please address Dept. 78

Eldorado
Electronics
2821 Tenth Street
Berkeley 10, California

18

This article starts on page 90

adjusted to match the scintillation pulse from a particular nuclide.

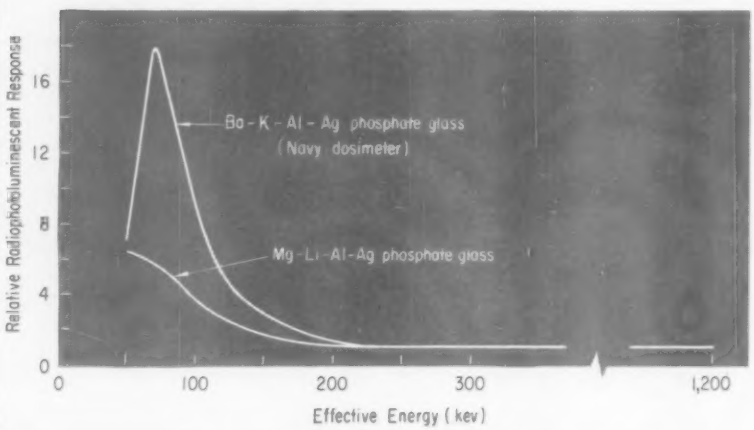
Performance

Generator frequency is stable to better than 0.5% at laboratory ambient temperatures. We chose a nominal 200-cps repetition rate to provide a brighter oscilloscope trace than is obtained when 60-cps power drives the customary mercury-wetted contact relay (mercury-switch pulse). In addition, it is sometimes desirable to check a scaler or counting rate meter at some frequency other than the customary 60 or 120 cps built in as a self-check in most commercial instruments.

We checked our amplitude stability against a Hamner N101 mercury-switch pulser with a pulse-height analyzer. There is no detectable drift between our transistor pulser and the mercury-switch pulser after the latter has had a 30-min warmup. (The N101 has cathode-follower output.)

Circuit

Our circuit is shown in Fig. 1. (The 2N168A transistor has just been discontinued by the manufacturer, but the 2N293 or 2N1086 can be directly substituted with no change in component values.) The photograph (Fig. 2) shows the size of the transistor pulser and one possible arrangement of circuit components. The 1.6-ma operating current comes from a 1,000 ma-hr mercury battery (Mallory RM-1).



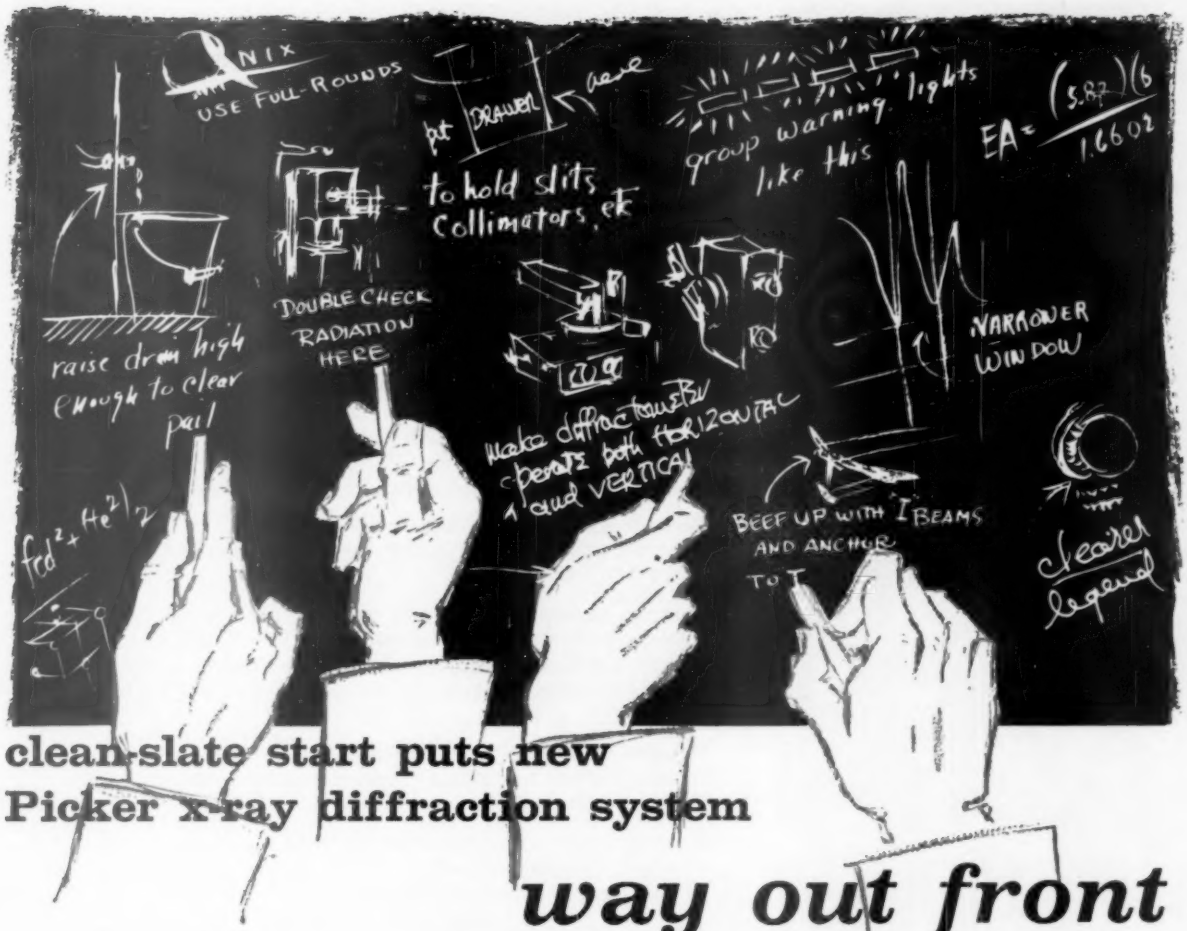
ENERGY DEPENDENCE of radiophotoluminescent glasses. Response to Co^{60} normalized to unity for both glasses

New Glass Dosimeter Is Less Energy-Dependent

By R. J. GINTHER and J. H. SCHULMAN
U. S. Naval Research Laboratory, Washington, D. C.

A newly developed radiophotoluminescent Mg-Li-Al-Ag phosphate glass has a sensitivity to low-energy gamma rays one-third that of the glass used in the dosimetry system of the U. S. Navy (see curves above). The lithium is also expected to provide an enhanced thermal-neutron sensitivity over that of the older glass (*1, 2*).

The Navy dosimeter (*3*), as well as the microdosimeter reported by Schulman and Etzel (*4*), employs as the sensitive element a radiophotoluminescent phosphate glass of the approximate composition (in parts by weight): 25 $Ba(PO_3)_2$, 25 KPO_3, 50 $Al(PO_3)_3$ and



clean-slate start puts new Picker x-ray diffraction system

way out front

start with a design group of experts wise in the ways of x-ray diffraction and fluorescence analysis. Give them two clear and simple goals (a) create the finest, most versatile apparatus you can and (b) make it easy to operate. Don't hobble their imaginations with "existing" components: give them a clean slate and plenty of time to boot.

You'll know how handsomely such a program can pay off the first time you see the spanking new line of equipment they've come up with.

Get the full story from your local Picker representative or write Picker X-Ray Corporation, 25 South Broadway, White Plains, New York.

new *versatility*

Answers every need of x-ray diffraction and fluorescence analysis. New x-ray tube. Two generators (full wave and constant potential). Two tables. Highly advanced diffractometer. Electronic radiation analyzer. Digital printout.

new *operating ease*

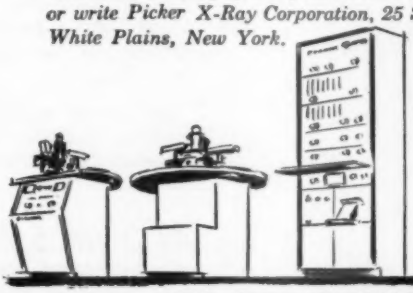
All operating parts within easy view and reach. Efficiently organized controls make working with it pleasant and convenient.

new *radiation safety*

Utilizes radiation efficiently, yet keeps it safely within bounds.

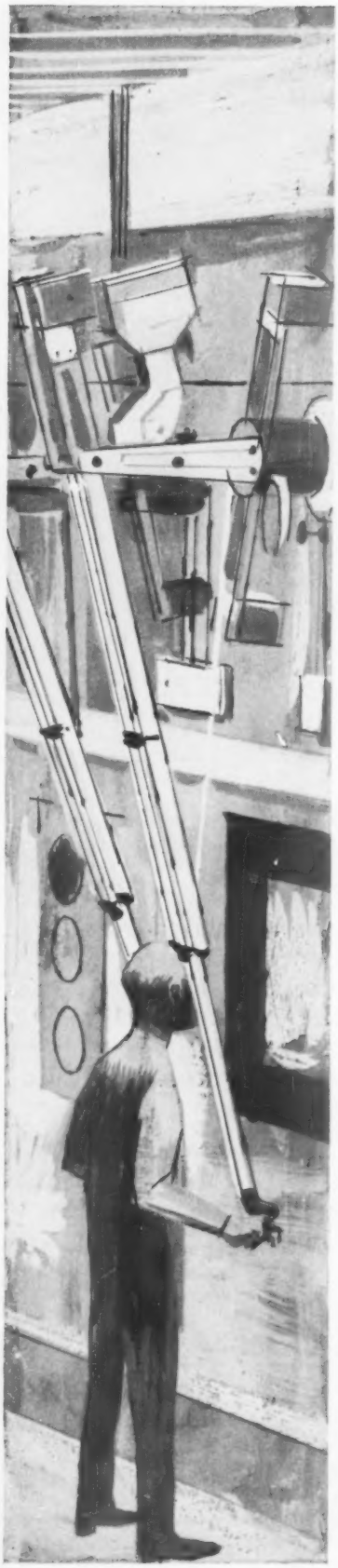
old-*fashioned service*

Backed by the expert engineers of the Picker service organization. Local offices and service depots the country over.



Picker x-ray

no capital investment if you'd rather rent ● ask about the PICKER RENTAL PLAN



Research Engineers and Scientists

needed for continuing expansion
in nuclear technology at

Atomics International

Heat Transfer and Fluid Mechanics. Both theoretical and experimental heat transfer research, fluid mechanics and hydraulics research, including hydro-dynamic performance of fuel elements, and investigation of convective and boiling heat transfer characteristics of reactor coolants.

Reactor Analysis. Complete nuclear, thermal and structural analysis including criticality, flux and power distributions and fuel cycle analysis.

Systems Analysis. Analysis and simulation of complete nuclear power plants to develop reliable, unattended, completely automatic control and instrumentation systems, including reactor kinetics, dynamics, hazards and reliability analysis.

Reactor Shielding. Experimental and analytical shielding techniques and materials development for both central station and compact power reactors.

Reactor Operators. Engineers to install, operate, maintain and modify compact reactor power plants. Good knowledge of test instrumentation required.

Reactor Power Plant Engineers. To assume full responsibility for planning execution and analysis of test reactors and power plants leading to fully automatic, remote systems.

Space Environmental Testing. Component development and space environmental testing of nuclear power plant components including high vacuum, vibration, shock, thermal and orientation testing.

Process Development. Development of chemical processes for organic cooled and moderated reactors on bench and pilot plant scale.

Radiation Effects. Analysis of radiation effects on organic and solid electronic materials, including experimental determination of physical and thermal properties of organic fluids at elevated temperatures.

Process Instrumentation Engineers. Thorough knowledge of process instrumentation and control systems. Background should include experience in chemical process plant, refinery, power plant or reactor instrumentation.

For specific details write: Mr. C. D. Newton, Personnel Office, Atomics International, 8900 DeSoto Avenue, Canoga Park, California.

ATOMICS INTERNATIONAL
A DIVISION OF NORTH AMERICAN AVIATION, INC.

Metallurgists and Engineers

Reactor Materials. Investigation and analysis of mechanical and physical properties of nuclear fuels and materials for high temperature reactors. Development of ferrous and non-ferrous alloys.

Fuel Element Engineering. Complete analysis and design of fuel elements including nuclear, thermal, material, mechanical and cost analyses. Theoretical determination of creep and stress under all operating and fuel handling conditions. Environmental and non-destructive testing.

Fuel Fabrication. Development of equipment and processes for fabrication and assembly of fuel elements. Develop melting, alloying, forming, welding and joining processes for new alloys and ceramic materials.

Corrosion Research. Corrosion and heat transfer research on new materials and advanced liquid metals at elevated temperatures.

Hot Cells. Design and development of hot cell equipment and processes. Remote handling of radioactive materials, especially metallurgical and physical testing.

Irradiation Experimentation. Design and conduct irradiation experiments on reactor fuels over wide range of radiation and temperature conditions, including simulation of conditions expected in full scale power reactors. Development of equipment and techniques for post-irradiation testing and evaluation of these experiments.

For specific details write: Mr. C. D. Newton, Personnel Office, Atomics International, 8900 DeSoto Avenue, Canoga Park, California.

ATOMICS INTERNATIONAL
A DIVISION OF NORTH AMERICAN AVIATION, INC.

This article starts on page 92

8 $AgPO_3$. Since some of the ions employed in the glass are of relatively high atomic number, the glass is highly absorbent for low-energy X-rays, rendering it more sensitive to these radiations than to harder radiations such as Co^{60} gamma rays. As the illustration shows, this glass is about 18 times more sensitive to 70-kev X-rays than to 1.2-Mev gamma rays. The Navy dosimeter is rendered satisfactorily energy-independent ($\pm 20\%$ from 80 kev to 1.2 Mev) by the lead shields developed by Klick (*5*).

A less energy-dependent glass minimizes the size or complexity of the shields that must be employed. This is particularly desirable in the determination, with 1-mm-diameter glass needles (*4*), of doses delivered in tissue.

How It Was Done

A considerable improvement in energy dependence can be realized by replacement of as many of the heavy elements of the glass with light elements as is consistent with the retention of good glass-forming properties and good dosimeter sensitivity.

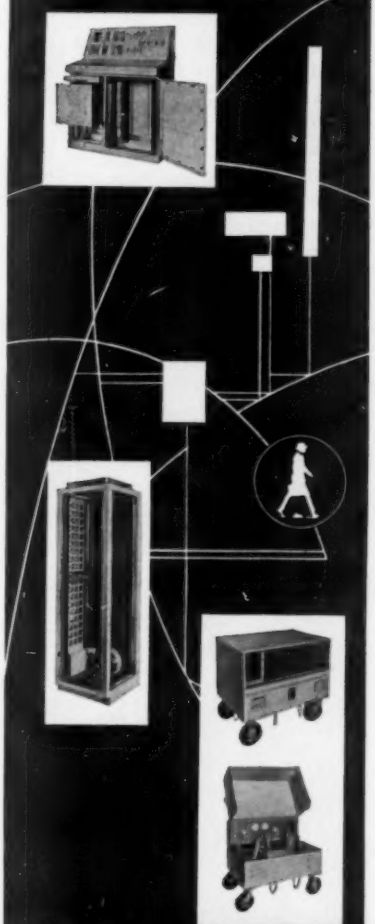
One possibility is to substitute boron for phosphorus, that is, to use a borate glass. However, those radiophotoluminescent silver-activated borate glasses prepared to date in our laboratory have been less sensitive than phosphate glasses. It therefore appeared advisable to retain phosphorus as the glass former. Silver could not be replaced, as we are aware of no other ion that will serve as a radiophotoluminescent center in phosphate glass. Aluminum is a relatively light element that to our knowledge has no substitute in providing chemical resistivity and freedom from devitrification in phosphate glasses (*6*).

Barium and potassium are then the only two replaceable elements. Substitution on a weight basis of $Mg(PO_3)_2$ and $LiPO_3$ for the $Ba(PO_3)_2$ and KPO_3 of the original glass yielded a product having similar glass-working properties and similar sensitivity to 1.2-Mev gamma rays, but having the energy dependence shown in the illustration.

BIBLIOGRAPHY

1. S. Kondo, private communication
2. E. R. Ballinger, private communication
3. J. H. Schulman, W. Shurcliff, R. J. Ginther, F. H. Attix, NUCLEONICS **11**, No. 10, 52 (1953)
4. J. H. Schulman, H. W. Etzel, *Science* **118**, 184 (1953)
5. C. C. Klick, U. S. Patent 2,752,501 (1956)
6. N. J. Kreidl, W. A. Weyl, *J. Am. Ceram. Soc.* **24**, 372 (1941)

New technical requirements require new techniques



If you have a fabrication problem with special or exotic alloys, the Falstrom Company has the engineering skills, the experience and special facilities to advise and assist you. Falstrom performance, as one of America's leading custom metal fabricators, has been recognized by the award of many critical contracts to military specifications.

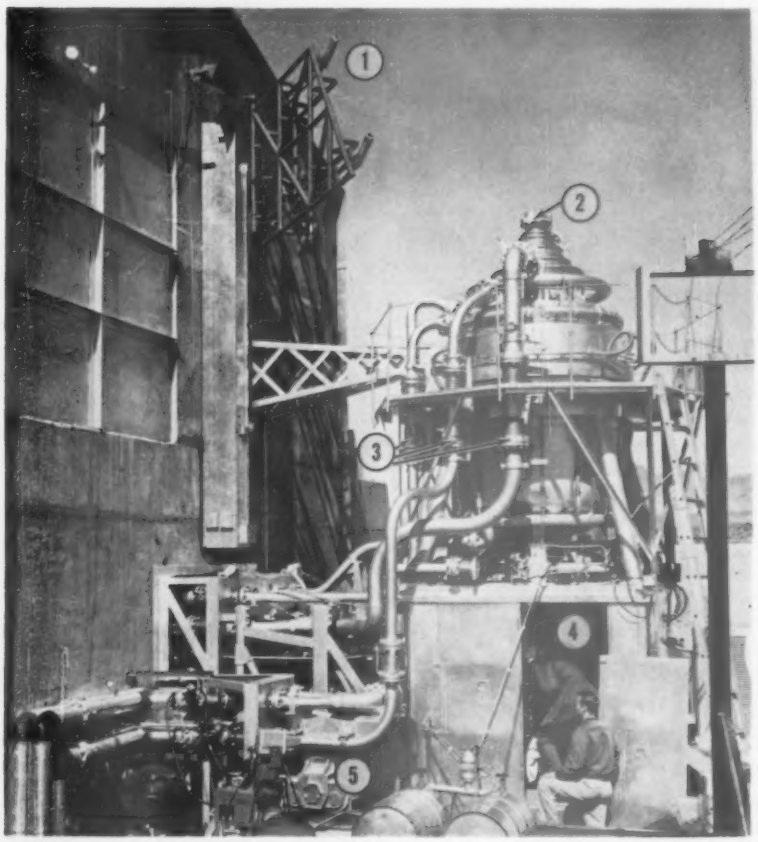
In light or heavy gauge, in steel, stainless, aluminum, titanium and other metals.

Send blueprints for prompt quotation or call PRescott 7-0013 for a Field Sales Engineer.

Custom Metal Fabricators for 90 years
FALSTROM COMPANY
181 Falstrom Court • Passaic, N. J.

A Closer Look at the *Real* Kiwi-A

Nuclear rockets are in the air—figuratively if not literally—as AEC prepares for a second reactor test under its Project Rover this summer. Principal embodiment of the program (NU, July '58, p. 69) has been the Kiwi reactor experiment. While most Kiwi details remain classified, NUCLEONICS has been able to shake loose a few facts and a striking photograph (see below). The facts on the late Kiwi-A which follow have been gleaned from various reports and speeches made by members of the AEC-NASA team that is exploring the fields of nuclear rocketry:



FIRST UNCLASSIFIED PHOTOGRAPH of the actual Kiwi-A, first test vehicle in AEC-NASA Project Rover nuclear rocket program. [Earlier photos (NU, Jan., 1959, p. 27) were of mockup.] The Los Alamos-designed reactor is shown nozzle-up on its railroad flatcar during pretest checkout of instrumentation. Igniter (1) swings out from test-cell wall and lines up with reactor nozzle (2) to burn hydrogen emerging so as to prevent an explosive accumulation of the gas in the atmosphere. Auxiliary system fired smoke into the exhaust flame to mark it for cloud-tracking purpose. Rectangular box (4) below reactor contains control-rod actuators and intermediate terminals for instrumentation. A concrete plug (not shown) at the front of the flatcar fitted into a matching hole in the test cell wall, to carry circuits from the privy into the protected area of the test cell. Piping (3) for H_2 propellant and water cooling attaches to mating fittings on test-cell wall by quick-disconnect couplings. After testing, test car was jacked away from these connections by remote control and removed by rail (5) to the disassembly area two miles away for post-mortem examination. For further information on Kiwi-A see story above

- The core was made up of a large number of graphite fuel plates imbedded with uranium; the graphite served as both a neutron moderator and a structural matrix for the uranium fuel.
- Hydrogen-gas coolant flowed under pressure through the channels between the plates and on out the thrust nozzle.
- The control rods were grouped together at the center of the core and included a main regulating rod, 7 shim rods, 4 scram rods and a small oscillator rod.
- A neutron reflector separated the core and the outer pressure vessel; both the reflector and vessel had their own internal cooling channels.

The Kiwi-A test program, described as extremely successful, culminated in a test run on July 1 last year at "the power specified as the test objective." Although the reactor survived this final trial in operating condition, it is being dismantled and subjected to a thorough post-mortem by radiochemists and metallurgists. They will collect information on material performance at the design power density and temperature—information that could only be had by operating a full-scale test such as Kiwi-A.

Reactor control during the rapid startup seemed, before the experiment, to be particularly touchy. The job was successfully carried out by an analog computer that received information on temperature, power level and propellant flow rate, compared these with design conditions and transmitted commands to the power-plant controls. During the full-power run the analog used 800 intelligence channels.

Preparations are now underway to test a second test vehicle, Kiwi-A′, about the middle of this year; Kiwi-A′ will be "essentially identical in external appearance" to Kiwi-A, but will incorporate a "vastly improved fuel element, which will be an early step towards important space-vehicle applications."

Recently the AEC was able to restore $11- of the $16-million cut from the Rover program in February by the Budget Bureau. The total budget is now $34-million.

Sodium Steam Generators Must Show Reliability

In addition to technical uncertainties concerning reactivity, suitability of core materials, and chances of a Na-D_2O reaction in the core, a major factor in dropping further work on the Sodium Deuterium Reactor (NU, March '59, p. 17) was concern about the economic reliability of sodium steam generators. Most other sodium-system components have proven their reliability for use with sodium at about 1,000° F; AEC's Sodium Components Development Program is studying problems in operating sodium systems up to 1,200° F.

But until the large sodium reactors now being built yield operating experience, new sodium-reactor concepts will not be pushed.

A large portion of the black eye sported by sodium components is due to the less than 50% success enjoyed in components tests during the Navy's S1G development program. In this 8-yr program (1949–57), in which a major portion of the $40-million that went into development, manufacture and test of sodium components was spent on steam generators, 26 new and rebuilt heat exchangers were tested—14 leaked, while 12 tests continued with no leakage for times up to 5,000 hr.

The EBR-1 has operated for 9 years—demonstrating that liquid-metal reactor coolants are technically feasible. But its simple steam generator would be costly if extrapolated to large power plants. The SRE, EBR-2 and Fermi reactors reflect three degrees of optimism in design and operation (and, thus, cost). The SRE has a double-wall tube all-stainless system, with mercury in the annulus. The EBR-2 steam generator has separate ferretic tubes for sodium and for water; braze alloy in the duplex tubes separates the fluids.

With a once-through bayonet configuration having a single-wall tube and no other barrier between the two fluids, the Fermi plant embraces the most optimistic philosophy. None of the sodium plants being built will generate steam over 900° F; thus the development of higher-temperature components still will play a key role. ("Report of the Sodium Heavy-Water Reactor Task Force," TID-8515, 1959.)

The Bellows You Need *Hasn't Yet Been Made!*

Your design is *new* — not a collection of stock items. Nor can your critical requirements be met by stock bellows.

Your bellows function is dependent on endless variables of temperature, pressure, atmosphere, stress.

The correct bellows assembly must be specifically designed for the job — and Robertshaw engineers are at your elbow with more *bellows answers* than anyone else!

Bellows can be brass, phosphor bronze, beryllium copper, monel, stainless steel, inconel, inconel-X . . . or other special metals to meet a critical situation.

NEW BOOKLET! *For technical data on Sylphon® Bellows — and cost-saving Bellows Assemblies — write for just-issued catalog* **GVR**

Robertshaw-Fulton CONTROLS COMPANY

FULTON SYLPHON DIVISION • Knoxville 1, Tennessee

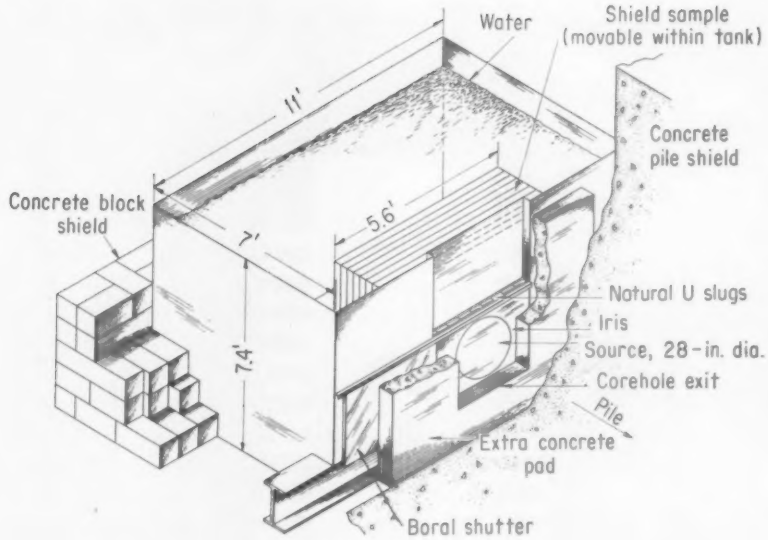


FIG. 1. LID TANK SHIELD FACILITY. Thermal neutrons from X-10 Reactor pass through hole in reactor shield and cause U^{235} in aperture to fission and release spectrum of radiation towards tank. Detectors in tank measure intensities of neutrons and gammas passing through experimental shield materials or mockups. Compensated ion chamber at core-hole exit monitors thermal neutrons from reactor so as to provide normalization factor for correcting shield data to constant fission rate in U plate. To permit measurement of background from reactor, boral shutters are placed over core-hole exit and outside U plate so as to absorb thermal neutrons from tank water. SP-1 fission plate (U slugs) is shown in place; boral iris forms source aperture

Calibration of ORNL Lid-Tank Fission Plates

By WHITTIE J. McCOOL,* *Pratt & Whitney Aircraft Div., United Aircraft Corp., Middletown, Connecticut*
and D. R. OTIS,† *Convair Division, General Dynamics Corp., San Diego, California*

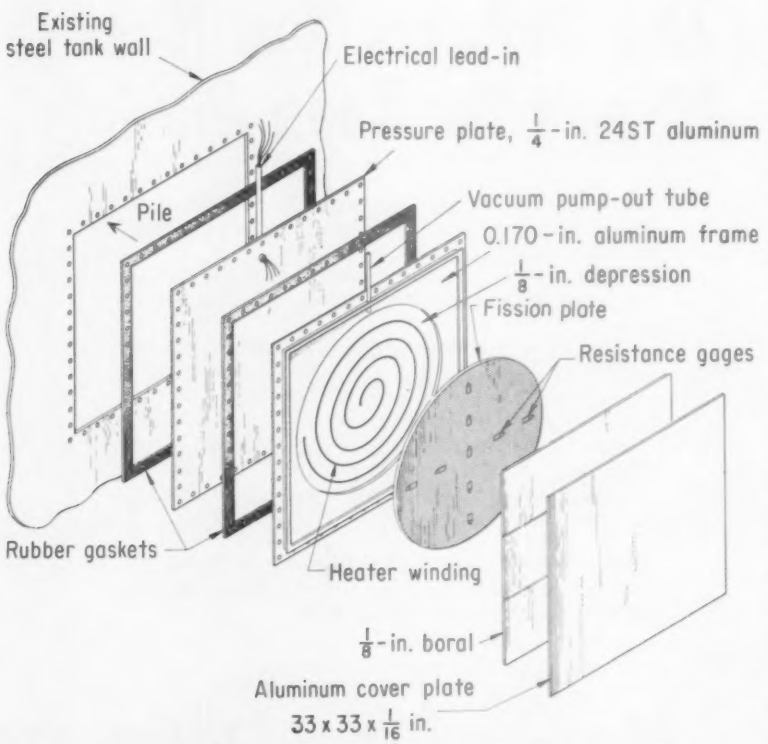


FIG. 2. SP-2 FISSION-PLATE consists of disk of pure 21%-enriched U, 0.060 × 28 in., held inside evacuated chamber by friction with chamber walls. Pressurization of void between pressure plate and aluminum frame, via lead-in tube, prevents distortion of assembly by hydrostatic pressure. Electrical leads, heater windings and resistance gages were used in calibration experiment

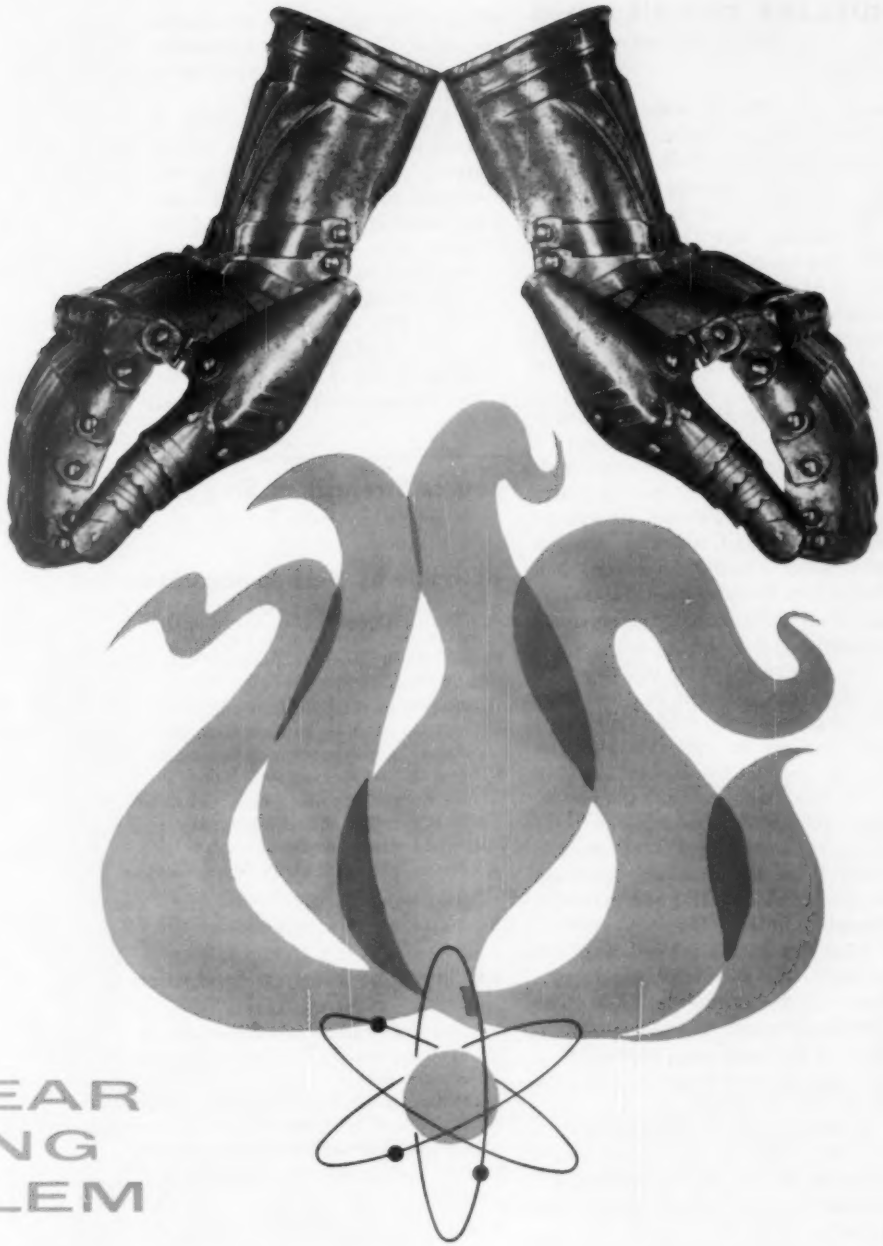
The Lid Tank Shielding Facility at Oak Ridge National Laboratory's X-10 Reactor is a classic facility for the experimental study of shields (see Fig. 1). Since 1948 several hundred experiments have been conducted with many different shield mockups. In that time two fission plates (*1*) have been used as radiation sources for LTSF: the SP-1 plate (shown in Fig. 1) was used from 1948 until its replacement, in 1955, by a much improved source, SP-2 (see Fig. 2). We calibrated the SP-2 fission plate in three independent experiments and used the data for a retrospective recalibration of SP-1, whose nonuniform geometry (given above) made its original calibration suspect. The combined results should prove useful for interpretation of all LTSF shield studies.

SP-2 Calibration

The three independent calibration experiments performed to determine the fission rate in SP-2 were: (a) thermal-neutron flux and utilization, (b) neutron-generation rate, (c) heat-gener-

* PRESENT ADDRESS: Alco Products, Inc., Schenectady, New York.
†PRESENT ADDRESS: Department of Physics, University of California, Berkeley, California.

OBJECT D'ART COURTESY OF THE WALTERS ART GALLERY, BALTIMORE, MD.



NUCLEAR
FUELING
PROBLEM
?

FRI can handle it In its search for new and better methods of handling nuclear fuels, FRI is currently conducting advance-concept investigations of refueling devices and components, control rod drives and couplings, and coolant systems for primary and secondary systems of the reactors. This development work is based on practical field-proven nuclear experience in component development supported by a background of over 25 years in the design, manufacture and testing of fluid handling and mechanical systems. ■ We would appreciate the opportunity of applying our knowledge and capabilities to the development of your nuclear systems. Write or call for consultation.

Nuclear Products Section
Flight Refueling, Inc.
Friendship International Airport
Baltimore 3, Maryland

Flight Refueling, Inc.

ation rate. Results were normalized to 3.7-Mw(th) operation of the X-10 Reactor with a 1-in.-thick lead gamma-ray suppressor inserted between the core-hole exit and SP-2.

1. Neutron flux and utilization. This first method of estimating fission rate in SP-2 was based on the product of incident thermal-neutron flux (integrated over the entire plate surface) and thermal-neutron utilization within SP-2.

The thermal-neutron distribution over the core-hole exit was measured by activating gold wires stretched horizontally across the opening, then correcting for resonance absorption, self-shielding and effective neutron temperature. Isoflux lines were then plotted over the plate surface and average flux determined by graphical integration.

The thermal-neutron utilization in the plate was measured in a transmission experiment in which gold foils were exposed to core-hole neutrons through various thicknesses (0–0.240 in.) of scrap material from the fission-plate fabrication. Corrections were made for hardening of the neutron spectrum in the uranium, spectrum hardening, self-shielding and resonance absorption in the gold foils.

As shown in the table, both these measurements were combined to estimate the fission rate in SP-2. The correction factor V was calculated from the isotopic assay and known fission and capture cross sections (*2*) of the fission-plate materials.

It is the practice in taking LTSF data to subtract the "shutter-closed" measurements from the "shutter-open" readings so as to eliminate background radiation from the X-10 Reactor. Since the above method predicts the fission rate with the shutter open, it was necessary to include a correction factor B, that accounts for thermal neutrons that leak through the boral shutter when closed and cause fission in the plate. B was measured in a transmission experiment through the boral shutter.

2. Neutron-production rate. The fission rate in SP-2 was estimated from the measured rate of emission of neutrons from the plate and the known average number of neutrons released per fission. Under equilibrium conditions the rates of production and loss are equal; thus to estimate the fission rate one has only to sum the neutron loss rates. The several mechanisms for neutron losses are summarized in the table.

In a water medium essentially all neutron absorptions occur at thermal energies. Hence N_1, the total neutron absorption rate in the Lid Tank water, was obtained by multiplying the neutron flux by the macroscopic thermal-neutron absorption cross section and integrating over the water volume. The thermal-neutron flux was mapped using a calibrated fission chamber.

The thermal-neutron absorption rate (N_2) in the boral sheet covering the fission plate was evaluated from integration over the surface of thermal-flux measured at the surface of the fission-plate assembly. We assumed an angular distribution of the Fermi type (*3*) and complete absorption of neutrons diffusing into the boral. (A Fermi distribution is justified since thermal-neutron diffusion from a water medium into a black absorber is quite similar to thermal-neutron diffusion from a moderator into a void.)

The escape probability P_1 of fission neutrons from the SP-2 assembly

(*Continued on page 122*)

Source Strength of SP-2 Fission Plate

• Estimate by Neutron Absorption Rate

Variable	Value	Est. error (%)
S, fission-plate surface area, cm²	3,980	±0.2
V, fraction of neutrons absorbed that results in fission	0.832	±1.0
N, normalization to constant pile power	1.00	±5.0
L, normalization to configuration using 1″ Pb gamma suppressor between fission plate and pile	0.788	±6.0
B, boral shutter leakage correction	0.971	±0.5
G, inverse-square geometry correction for difference in location of fission plate and gold wires	1.088	±3.0
F, thermal utilization factor	0.425	±3.0
ϕ, average thermal neutron flux, n/cm²/sec	1.35×10^8	±4.6
P, $SVNLBGF\phi$, fiss/sec	1.60×10^{11} ± 9%	

• Estimate by Neutron Production Rate

Variable	Value	Est. error (%)
N_1, neutrons absorbed in LTSF water,/sec	13.4×10^{10}	±15
N_2, neutrons absorbed in boral of fission-plate assembly,/sec	6.3×10^{10}	±20
y, average number of neutrons released per fission	2.46	±1.6
P_1, fraction of neutrons emitted in direction of LTSF that escape fission-plate assembly	0.98	±1
P_2, fraction of neutrons entering LTSF that remain	1.00	±5
$P = 2(N_1 + N_2)/(yP_1P_2)$, fiss/sec	1.64×10^{11} ± 13.5%	

• Estimate by Energy Absorption

Energy source	Mev/fiss	Fraction deposited in fission plate	Fission plate energy absorption (Mev)
Fission fragments	168 ± 5	1.00	168 ± 5
Betas	7 ± 1	1.00	7 ± 1
Prompt and fission-product gammas	12.1 ± 1	0.27	3.25 ± 0.2
Nonproductive neutron captures	1.0	0.3	0.30
Fission neutrons	5 ± 1	0	0
Neutrinos	10	0	0
Fission-plate energy absorption per fission, Mev/fiss			179 ± 5

P = 4.68 watts/(179 Mev/fiss × 1.60×10^{-12} watt-sec/Mev), fiss/sec
= 1.63×10^{11} ± 6%

One of a series

Payoff in portable photons

Samarium-145, Samarium-153, Gadolinium-153.
Scientists at the General Motors Research Laboratories began three years ago to measure and re-evaluate the nuclear characteristics of these rare earth isotopes — their half-lives, photon emissions, thermal neutron cross sections.

Conclusion: the radioisotopes had attractive possibilities in industrial and medical radiography, emitting almost pure gamma rays or X-rays (photons) in the low energy range of 30 to 100 kev.

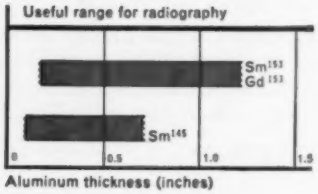
The transition from research to hardware came through two key developments. First, cermet pellets were fabricated using only a few milligrams of the rare earth oxides. Then the irradiated pellets were packaged in special bullet-size holders.

The resulting small, sealed radiographic sources are now being field and laboratory tested. Two excellent applications: "inside-out" checks of hollow shapes inaccessible to X-ray tubes, and radiography of thin steel sections and low density materials such as aluminum or human bone. For example, a recent medical milestone was a chest radiograph of a living person made with a Sm^{153} source. The portable exposure unit to shield the source weighed only 18 pounds.

This isotope radiography program is but one example of the work underway in GM Research's modern isotope laboratory — work that means, through science, "more and better things for more people."

General Motors Research Laboratories

Warren, Michigan



Sm^{153} exposure unit.

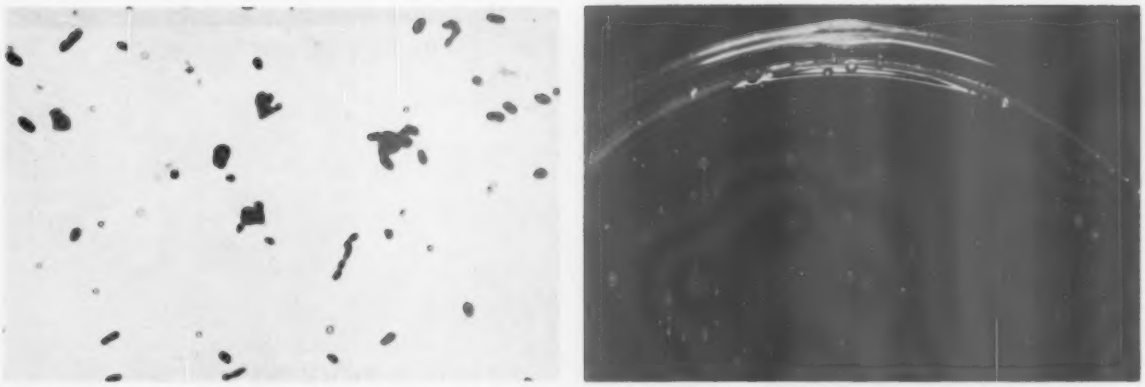


FIG. 1. BACTERIA that grew in Omega West reactor are shown at left, colonies formed on nutrient agar are shown at right

Bacterial "Infection" of the Omega West Reactor

By ERIC B. FOWLER, C. W. CHRISTENSON, EDWARD T. JURNEY and WILLIAM D. SCHAFER
Los Alamos Scientific Laboratory, University of California, Los Alamos, New Mexico

For most of the summer of 1958 the Omega West tank-type research reactor suffered from a bacterial "infection." More than 10^8 organisms could be found in each milliliter of reactor tank water (see Fig. 1). The bacterium—of the genus *Pseudomonas*—was probably able to multiply because the partially disintegrated anion resin supplied carbon and nitrogen for growth. The combination of resin fragments and bacterial growth caused a marked turbidity in the water, so much so that a 1,000-watt lamp could be seen only dimly at a depth of 4 ft in the reactor.

Both problems—turbidity and bacterial growth—were solved by combined purging, intermittent operation, filtration and change of resin. Felt-pad filters have been replaced by metallic filters to avoid the possibility of feeding organic matter to the reactor water. Bacteria have not reappeared.

What Happened

The Omega West Reactor is a solid-fuel, light-water-moderated and -cooled tank-type research reactor (*1*). Cooling water (total amount about 18,000 gal) is circulated downward through the core at the rate of 3,500 gpm and then cooled in an aluminum heat exchanger; the system is closed. About 35 gpm of the cooling water, at 85° F, is by-passed through a mixed-bed deionizer. The deionizer is preceded and followed by filters to remove suspended solids. Induced radioactivity is held to a tolerable level if dissolved solids are maintained below 1 ppm, which corresponds to a water resistivity of at least 0.5 megohm-cm.

In August 1957, a new thermally stable quaternary strong-base polystyrene anion-exchange resin was installed. Deionizer operating temperature was increased to 110° F. By the spring of 1958 its performance had degenerated to a point where it was difficult to maintain water at 0.5 megohm-cm even with regeneration every 5 weeks. Furthermore, colorimetric tests of reactor water indicated 50 ppm of silica, which was probably leached from the supporting quartz-rock bed at an accelerated rate owing to the increased operating temperature. This concentration was not significantly reduced by passage through the deionizer even immediately after regeneration.

In an attempt to remove the silicic material from the anion resin, a caustic regeneration at 160° F was employed (~35 lb NaOH per cubic foot of anion resin) with no apparent restoration of weak base-exchange capacity. For a period of weeks following this treatment the coloration and turbidity of the cooling water gradually increased. Normal research use of the reactor was impeded.

Microscopic Examination

Microscopic examinations of the water were made on June 24, 1958. There was no indication of algal growth, but particulate matter was prevalent and bacteria were demonstrated by direct staining. The bacterial count, on nutrient agar plates, was about 10^6/ml. Most surprising, however, from colony appearances and simple stains, the organisms seemed to represent a pure culture.

Further samples were taken from the main reactor tank and the tank exit lines. The populations were 5×10^8 and 10^3/ml respectively, suggesting a destruction of the organisms by passage through the region of intense radiation in the reactor core. (Since it was demonstrated in the laboratory that the organism was not strictly aerobic, it was felt that the difference in population was not due to difference in oxygen concentration.)

A microscopic examination of some of the red-brown floc in the water revealed a mass of fractured resin ranging in size from just visible at a magnification of 900× to particles about 100μ along the greatest axis. This material probably resulted from the hot-caustic treatment of the resin and together with the dissolved, disintegrated resin provided food for the organisms. The removal of a reactive group, such as the quaternary ammonium group, in a strong basic exchanger yields both carbon and nitrogen which would be available to the metabolism of the organisms.

Clearing Up the Trouble

For the following three months the reactor was operated intermittently

309
309S
309SCb
310
314
316
316L
317
317L
D319
D319L
17-4 PH*
17-7 PH*
PH 15-7 Mo*

Only Carlson produces all plate thicknesses in all these superior grades of stainless steel

IN addition to the more usual grades, Carlson regularly produces stainless steel plate and plate products in this wide range of superior analyses in any thickness. Many of these grades are included in our mill inventory; the others can be rolled to your order.

These chromium-nickel analyses were developed to more closely match the exact requirements of process, nuclear, and space equipment. Each has one or more of the following advantages: increased corrosion and/or heat resistance, good machinability, ease of fabrication, and exceptionally high physical properties with low temperature heat treatment. By selecting the grade that gives you the combination of advantages you want, your costs can be reduced and the trouble-free life of your equipment extended.

Write today for details on these superior grades and for inventory information on all types of stainless steel plates and heads.

*Trade marks of Armco Steel Corporation

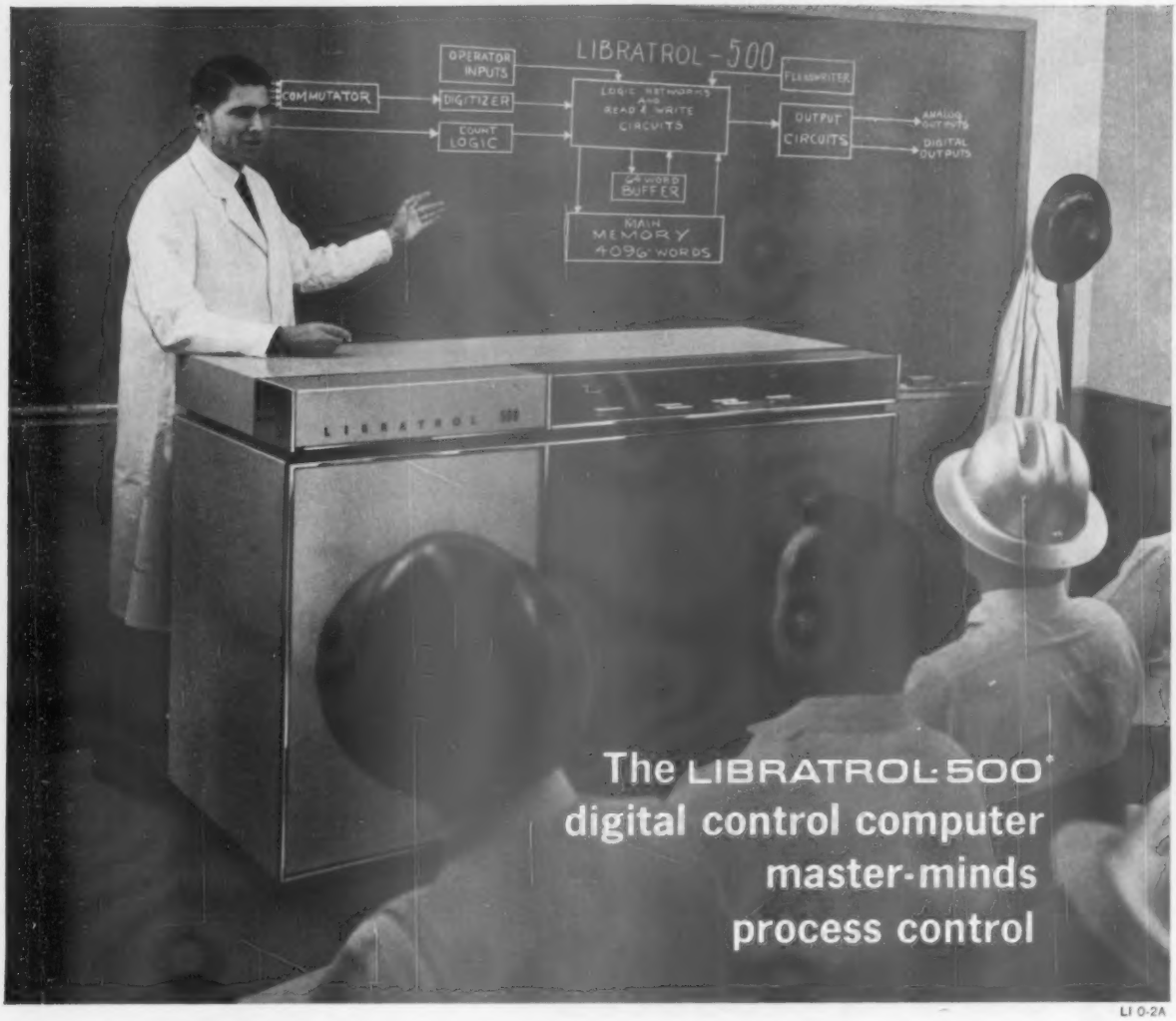
C

G.O.CARLSON Inc.

Stainless Steels Exclusively

138 Marshalton Road
THORNDALE, PENNSYLVANIA
District Sales Offices in Principal Cities

Plates • Plate Products • Heads • Rings • Circles • Flanges • Forgings • Bars and Sheets (No. 1 Finish)



LI 0-2A

The LIBRATROL-500* by Librascope is more than an on-line control computer.

■ Even more than a monitoring, computer-directing, and controlling system ... the Libratrol-500 can actually teach industry about its own processes ... can help to establish basic operating criteria.

■ Designed for present computer control techniques, the Libratrol-500 may be used: For the basic operating mode of monitoring and calculating, or the mode of computer-directed control. Or, the system may take full automatic closed loop control of the process.

■ With Libratrol-500, negligible time is used in preparing the data required for making decisions. In most cases it permits control decisions to be made at rates which match the time constants of the process involved.

■ *The Libratrol-500 is a high-speed digital computer-controller designed to handle:*

1. A large number of variables. 120 channels of voltage input data can be digitized and stored in less than 2 seconds, and data from several pulse sources may be introduced simultaneously. Number of inputs may be expanded to 1,000 or more channels by housing input modules in auxiliary cabinets.

2. Temporary information storage. Data can be recorded on the drum, used as needed in calculations, then dispensed with. Through this efficient use of memory space, the machine prints only the results of computations.

3. Rapid computation of control loop functions while handling on-line decisions and control. On one current installation, the Libratrol-500 completes a recurring calculation in one minute ... a problem formerly requiring 45 minutes computation by two engineers.

■ *A wide range of input-output equipment can be accommodated by the Libratrol-500, making the system especially suitable for pipeline automation, petroleum and chemical plants, iron and steel mills, gas and electric utility plants.*

The LIBRATROL-500 offers many unique advantages including:

.....READILY AVAILABLE LIBRARY OF SUBROUTINES.

.....INTERNAL TRUE BINARY REAL TIME REFERENCE.

.....31-BIT WORD LENGTH.

OPERATING INFORMATION

Computer type: General purpose digital.
Memory type: Magnetic drum.
Main memory capacity: 4096 words.
Buffer memory: 64 words.
Add time (Excluding access): 0.25 milliseconds.
Multiply time (Excluding access): 15 milliseconds.
Real time clock: Internal, binary.

■ The Libratrol-500 is typical of Librascope's leadership in creating new computer concepts ... a 22-year leadership based on uncovering needs and meeting them with advanced designs, reliable computing systems.

There's a Librascope applications engineer with experience in your industry. Without obligation, he will provide applicable case studies. And on request, he is available to make a feasibility study for computer control of your plant. For complete details, write: Department 340 Librascope, Inc., *808 Western Avenue, Glendale, California.*

LIBRATROL 500*

by LIBRASCOPE *a division of* GENERAL PRECISION, INC.

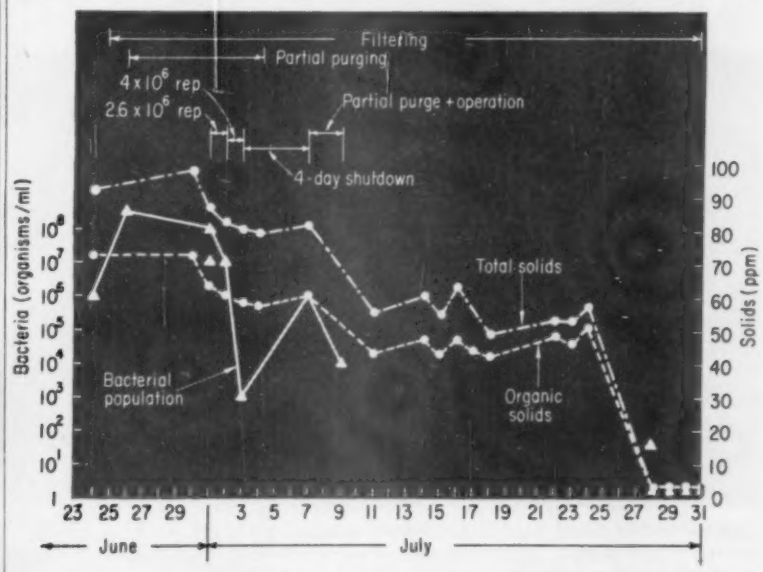


FIG. 2. BACTERIAL COUNT and solids in reactor water. Note that bacteria multiplied rapidly after shutdown and that short periods of operation decreased growth. However, operation by itself did not completely sterilize water. Control of organism required removal of food by purging and filtration

for short periods and the water in the reactor tank was purged as much as possible. It was thought that the 75-μ felt-pad filters might be a source of inoculum and for this reason they were replaced by 20-μ stainless-steel filters on July 4. Stagnant water in the fuel-element storage well contained about 10^{12} organisms per milliliter. The storage well was purged to eliminate this source of inoculum from the reactor system.

A summary of the results of the treatment is shown graphically in Fig. 2. Partial purging and improved filtration reduced the total solids and organic matter by about 40% over a period of 1 month. However, the quality of the water was improved markedly only after the complete change of resin on July 25. There was continued improvement in water quality, and by September 10 water clarity had been restored and the water was sterile.

Although heat sterilization of the reactor through operation without cooling seemed plausible, this procedure was discarded as undesirable from the standpoint of possible damage to reactor components. Treatment with antibiotics was rejected on a cost basis; chemical treatment was not possible because of the danger of corroding aluminum components.

What Organism?

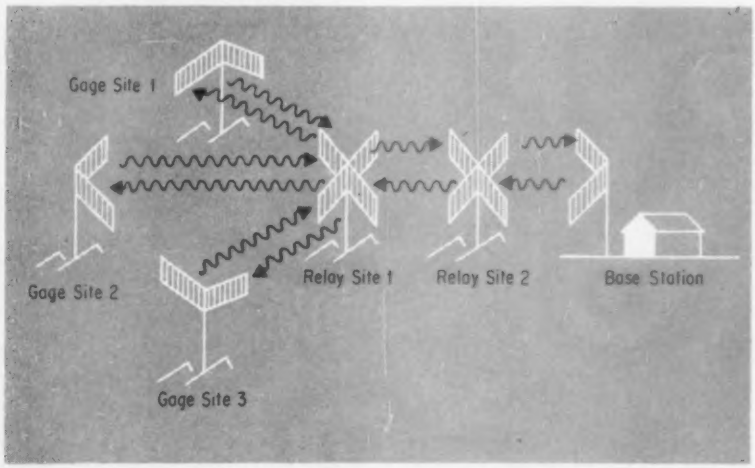
Preliminary work reveals the organisms belong to the genus *Pseudomonas*. They are short, gram-negative rods often paired. They do not ferment dextrose or lactose with acid or gas production and do not form pigment at 20° C or 37° C; they are nonmotile. Spores were not present; the 10-min thermal death point is about 68° C. The possibility of a mutant cannot be ignored but is rather remote.

Since the organism does not form pigment, the color in the water was probably due to particles of resin and material dissolved from the deteriorated resin. Although the organisms contributed to the over-all turbidity, their removal would not have completely solved this part of the problem. Filtration was also necessary to remove particles of suspended resin.

Lea (*2*) suggests that exposure of 10^3–10^4 rep are lethal to such organisms as *E. coli*. The average dosage received by organisms in the reactor was probably in excess of 10^6 rep; this and other evidence suggest that the organism might have a radiation resistance above average. This aspect is being investigated further.

BIBLIOGRAPHY

1. Nucleonics **14**, No. 8, 51 (1958)
2. D. E. Lea, Actions of Radiations on Living Cells, p. 316 (The Macmillan Co., New York, 1947)



GAMMA SNOW GAGE USES TELEMETERING to record detector pulses in snow field on counters at base station. System replaces ski-and-snowshoe surveys to find out how much water will run off in spring and summer to fill rivers and reservoirs

Telemetering Broadens Gaging and Monitoring

Radiation-detection systems are becoming bigger and bigger—at least in area. As they grow, radio data-transmission links are being called into play. At the National Reactor Testing Station adding telemetering to conventional detectors has made it possible to interrogate as many as 256 remote radiation monitors from a single spot. In another system, gamma gages in the mountains of California, Washington and Idaho are telemetering the amount of snow 70 miles away in less time than it takes to strap on a snowshoe.

Telemeter Monitors

Motorola is developing a sophisticated telemetering system for use by the AEC around the National Reactor Testing Station in Idaho. Up to 256 detectors—G-M tubes, scintillation crystals, ionization chambers—can be interrogated, and their answers can be recorded in 2 min. Tone bursts deliver binary-coded signals over a standard two-way radio communication system.

The operation sequence starts with a coded "Store" signal directing a remote monitor to accumulate data and hold it for 30 sec. Later a "Report" signal calls for transmission of the data in binary code. Since the ionization chambers used produce data in analog form, an analog-to-digital converter is provided with each of them. Once the system gets going, a "Store" signal for one station is a "Report" signal for another.

Snow Gages

Considerably simpler are the "biggest" gamma gages in the world, two systems for measuring Western snowfall and telling engineers how much water will come down river to cause floods, fill reservoirs, irrigate crops and turn turbines. In each of the systems, information from three gage sites in the snow fields passes by way of two relay stations to a base station as much as 70 miles away (see figure). Surveying trips by ski and snowshoe to weigh core samples are no longer necessary.

Each gage site has a radioactive source on the ground, a detector overhead, a transistor receiver to hear queries and a vacuum-tube transmitter to send answers. In operation the base station sends out a "Query" signal, a steady audio modulation on a VHF carrier. The receiver at one of the gage sites, always on, responds to the audio tone and activates the gage-site transmitter. (On its way up the mountain the signal has caused receivers at the two relay stations to turn on transmitters in the same manner.) As the gage-site transmitter goes on, it sends out its own audio tone on a return VHF carrier, and as this tone reaches the base station by way of the relay stations, it turns on counting and printing equipment.

Counting procedure. With communication links in operation, disintegrations at the gage site can actuate counters at the base station with their messages about snow depth. The source is 40 mc of Co^{60}. The detector is a 1½-in. NaI(Tl) crystal coupled to a transistor pulse-height analyzer, four-to-one count reducer and pulse shaper. Pulses go directly to the base station as modulations on the broad-band VHF carrier. The base station automatically times a preset count and then transmits a third audio tone as a "Turn-off" signal.

The system can be interrogated manually or programmed to make its own interrogations on a regular basis. If a "Query" tone from the base transmitter fails to produce a "Response" tone from a gage site, the base station waits 20 sec and then records the count anyway. If no count arrives it records this fact for the attention of maintenance personnel. If the gage-site fails to receive a "Turn-off" signal, it turns itself off after 5 min.

Liquid Scintillator Oxygen Detector

Some components of gas mixtures show their presences by the quenching action they produce when the mixture bubbles through a liquid scintillator. An experimental oxygen detector uses the effect.* The gas mixture is bubbled first through a tube of scintillator solvent and then, properly saturated with solvent, through a tube containing PPO and POPOP exposed to Sr^{90} betas. Decrease in scintillation meas-

*D. J. Chleck, J. Brinckerhoff, W. Hadley C. A. Ziegler, *Rev. Sci. Instr.* **30**, 37 (1959).

ures oxygen in the range 0.1–100%. If bubbles are fine enough, the system will operate continuously. Other quenchers could be detected.

Bibliography for Users of Nuclides

Recently available is the AEC revision of its booklet "Special Sources of Information on Isotopes" (TID-4563). 344 items include journals, textbooks, bibliographies, reports, etc. The list is broken down into the following categories: general, basic texts, procurement, properties, isotope uses, irradiation services, laboratories and equipment, radiation safety, waste disposal, legislation, development and assistance programs, lists of users, stable isotopes. The book is available free from the Office of Isotopes Development (USAEC, Washington 25, D. C.).

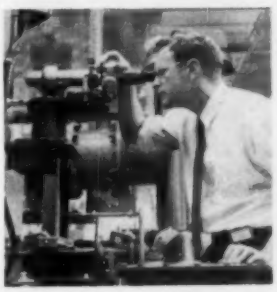
Photon Activation Finds Beryllium

Photon activation has found itself a paying job. A commercially available probe for field exploration uses a gamma source to activate beryllium and detects γ,n neutrons with a boron-loaded phosphor.

An 80-mc source of 60-day Sb^{124} supplies a multitude of gamma photons, 76% of them with energies greater than the 1.66 Mev required to activate beryllium. In use the source fits in a cavity in a 15-lb shield; the shield is attached to the base of a 10-lb phosphor-photomultiplier detector carried on an 8-ft pole between two men. For storage, source and shield go into an 80-lb castle.

A 5-in. polyester–zinc-sulfide phosphor loaded with boron detects neutrons with twice the efficiency of an enriched-BF_3 counter. An adjustable discriminator can be set to reject gamma pulses in the phosphor and accept n,α pulses from B^{10}. Accepted signals go to earphones or a portable counting-rate meter.

Nuclear Enterprises Ltd., Winnipeg, developed the "Berylometer," which is manufactured and marketed in the U. S. by the Western Division of Nuclear Corporation of America, Burbank, Calif.



Nuclear particle accelerators designed and built by High Voltage Engineering Corporation are standard research equipment in virtually every major physics laboratory in the Free World.

The outstanding acceptance of these instruments by Science, Medicine and Industry has been due chiefly to intensive and continuing research both under Company sponsorship and in cooperation with government, academic and private institutions. This experience has given the men of High Voltage unique understanding of many phenomena which are becoming increasingly important in modern physics, nuclear engineering and space technology. Areas of research activity include:

RADIATION POWER GENERATION
PARTICLE ACCELERATION
HIGH VOLTAGE ELECTROSTATICS
ELECTRON AND ION OPTICS
PARTICLE ANALYSIS
HIGH VACUUM
MAGNETICS
ION PROPULSION
MICROWAVE ELECTRONICS
RADIATION CHEMISTRY
NEUTRON ACTIVATION ANALYSIS

High Voltage is qualified to solve problems in these areas leading to specialized equipment for fundamental and applied research in nuclear, plasma and solid state physics, chemistry and biology.

The brochure, *This is Research,* describes our research accomplishments and capabilities. Ask for a copy on your letterhead.

HIGH VOLTAGE ENGINEERING CORPORATION
BURLINGTON, MASSACHUSETTS • U.S.A.

Complementary Effects of Heat and Radiation on Food Microorganisms

By LLOYD L. KEMPE, *University of Michigan, Ann Arbor, Michigan*

Heat and radiation used together may be more effective for food preservation than either one alone. Each of these agents can be somewhat damaging: overcooking food sometimes reduces its nutritive value; radiation can produce off-odors, off-flavors and degraded textures. Experiments show, however, that a radiation dose that is about one third of the sterilization dose reduces the heat treatment required to sterilize to about one fourth of what it is without radiation.

Consider, for example, a canned beef. Heat enough to sterilize the center may overcook the outside. Radiation enough to sterilize it produces off-flavors. But one can hope to use a comparatively small radiation dose and then sterilize the beef with an amount of heat too small to overcook.

Heat, Radiation, Bacteria

It has been amply demonstrated that microorganisms are more easily killed by heat after treatment with ionizing radiations (*1–5*). The literature also indicates that a similar sensitization of microorganisms to heat follows irradiation with ultraviolet (*6–8*) and even visible light (*9*). With visible light, photosensitive dyes must be present. Since sensitization to heat follows treatment with radiations that are not ionizing, the combined lethal effect may really be photochemical. This appears reasonable because ionizing radiations passing through matter are ultimately degraded to the photochemical range (*10*).

Early scientists in the field postulated that the combined lethal effect of ultraviolet light and heat (which is synergistic—greater than the sum of its parts) comes about through the increased sensitivity of cell proteins to denaturation, which they felt is a chemical reaction with water (*11*). This agrees with Bovie's observation that ultraviolet irradiation of egg albumen alters its heat coagulation (*12*) and Lewith's work showing that the lethal action of heat alone is associated with protein coagulation (*13*). Whether this theory is correct or not, the increase of the lethality of heat by radiation has been observed with ultraviolet and visible light as well as with gamma, beta and X-radiations.

Food Treatment

With the development of large sources of ionizing radiations, attention has been directed to their possible application for commercial food sterilization. Unfortunately large doses are required: 4.5 megarads is presently indicated as a sterilizing dose by extrapolation of data taken in canned meat (*14*). A similar dose has been recommended for killing viruses (*15*).

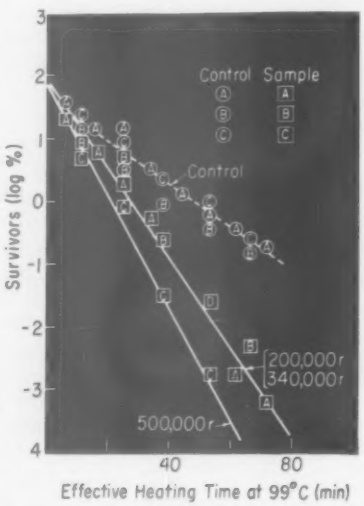


FIG. 1. SPORE CULTURES in test tubes are more easily killed by heat after preirradiation with Co^{60}. *C. botulinum* spores were irradiated and heat-treated in nutrient broth at pH of 6.7 (*2*)

But radiation increases lethality of heat for microorganisms. We have been carrying out tests of the application of this observation in food processing for a number of years.

Studies in Microbiology

The combined irradiation-heat effect is apparent with bacterial spores. The effect was tested in M/15 phosphate buffer at *p*H 7.0, in nutrient broth and in gelatin (*1–3*). For this purpose *Clostridium botulinum* and PA 3679 spores were grown, harvested, washed, suspended in the selected medium and dispensed into ordinary cotton-plugged test tubes. One group was first heat processed and then placed in our Co^{60} irradiation source (*16*). Portions were removed periodically for determination of the number of viable survivors. The other group was irradiated first and then immersed in a boiling water bath; at proper intervals, samples were removed for counting.

Preheating does not sensitize spores to subsequent lethal action of gamma radiation, but Fig. 1 shows that preirradiation does sensitize spores to heat; it also shows that the synergism increases with preirradiation dose. From these tests we conclude that the F_0 value for *C. botulinum* spores can be reduced at least fourfold by preirradiation with gamma rays from Co^{60} (*2*). The effect is less in gelatin and nutrient broth than in phosphate buffer. (F_0 is defined as the number of minutes at 250° F required to sterilize the system when the thermal-death-time curve—log of killing time as a function of temperature—has such a slope that a tenfold change in killing rate requires a change of 18° F.)

Canned Foods

With this microbiological fact established, the next step is evaluation of the combined effect in canned foods (*17, 18*). We initially selected ground beef for study, and now we are also testing green peas. Packs of beef are inoculated, some with *C. botulinum* and some with PA 3679 spores. This involves packing preheated ground beef into No. 1 picnic tin cans, setting the can lids loosely in place and heat processing for 1 hr with 15 psig steam. Then we inoculate the meat at the approximate geometric center with 1 ml of a water suspension of spores; the cans are sealed, cooled in ice-water, irradiated and heated.

A run consists in irradiating a group of cans to the same dose, heat processing groups of four cans to several "equivalent-processing-time" values, then incubating the cans at 85° F. An equivalent-processing-time value is the number of minutes at 250° to which the

NEW.....

Model 34-12 Transistorized 400 CHANNEL ANALYZER

- Ferrite Core Memory
- External Programming
- Memory Subgrouping
- Time Analyzer Mode
- Live Display on 5" CRT
- Crystal Controlled Live Timer
- 10^5 Count Capacity
- Address Identification
- 0.5% Linearity
- Prompt and Delayed Coincidence and Anti-Coincidence
- Spectrum Transfer Circuit
- Auto-Print
- Auto-Record
- Print and Record Simultaneously (OPT.)
- Dead Time Meter
- Auto Transfer Circuit
- Free Course of Instruction
- Installed by Factory Engineer

RIDL announces a new 400 Channel-Analyzer

To the RIDL family of transistorized analyzers is added a new 400-channel analyzer—the Model 34-12—now in production and being delivered. The Model 34-12 may be operated as a Multichannel Pulse Height Analyzer or as a Multichannel Scaler (Time Analyzer).

The Model 34-12 is designed to save valuable man-hours in the laboratory by providing full automation through such features as Auto-Print, Auto-Record and an automatic transfer circuit. A built-in crystal controlled live timer allows automatic dead time correction. The addition of automatic background correction allows final data readout without laborious manual corrections and/or replotting of data. The Model 34-12 may also be used as four simultaneous 100-channel analyzers without loss of resolution.

To this maximum development of automatic data gathering and analysis, RIDL now adds a new focus, AUTOMATIC DATA PROCESSING. This brings the ultimate in automation to the Model 34-12. To normal printing and plotting is added readout on magnetic tape, punched tape, or serial entry printers. This allows either system or instrument control or programming, multiple detector data processing, or sorting and routing of selected data. Whatever your data readout and processing needs may be, our staff is ready at all times to discuss them with you.

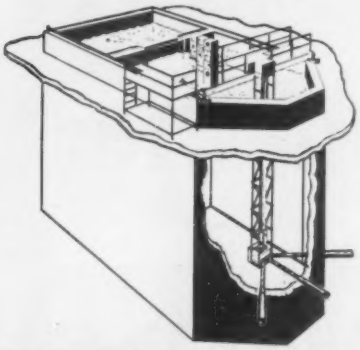
The Model 34-12 is another of the NEW line of instruments designed and developed by RIDL. Whatever your instrumentation problems, RIDL has the solution. Our staff is always available to answer your inquiries. For complete information on the Model 34-12 400-Channel Analyzer, write Department WB today.

RIDL INC.

Radiation Instrument Development Laboratory, Inc.

5737 SOUTH HALSTED STREET • CHICAGO 21, ILLINOIS
PHONE: TRiangle 3-2345 • Cable Address: RADILAB

1 x 10⁹ ROENTGENS WITHOUT DETERIORATION



PHENOLINE
PROTECTIVE COATING SYSTEM
for REACTOR POOLS STORAGE TANKS RETENTION PITS

Phenoline AEC-600 is a catalyzed modified phenolic 4-coat system, 34 mils thick, for lining concrete or steel vessels in nuclear installations. It consists of Phenoline 300 Orange Primer, 2 coats of Phenoline 302 with high water barrier characteristics, and a topcoat of light-reflective Phenoline 300 White. This system has been thoroughly proven in numerous successful field installations. Its principal features are:

1. **Tight barrier resistance to demineralized water penetration. 3 year's continuous immersion service tests show no blistering, flaking, cracking or softening.**
2. **High resistance to gamma radiation, with no breakdown under accumulations of at least 1 x 10⁹ roentgens.**
3. **Smooth, mirror surface, easy to decontaminate with detergent cleaning.**
4. **Excellent bonding strength to concrete or steel surfaces.**
5. **100% solids, providing heavy film thickness at moderate cost.**

Carboline maintains a specialized Nuclear Projects Department to assist in solving your coating problems. Write today for technical data and specifications on Phenoline coating systems for nuclear reactor facilities and processing plants.

Atlanta • Boston • Chicago • Denver Detroit • Houston • Los Angeles • Mobile New Orleans • New York • Philadelphia Pittsburgh • San Francisco • Tampa Toronto • Tulsa

carboline COMPANY

Coatings with Nuclear Experience

32-P Hanley Industrial Ct. St. Louis 17, Mo.

This article starts on page 108

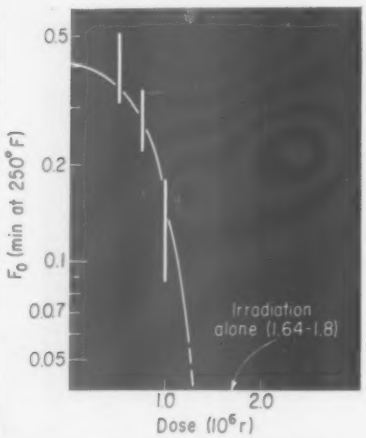


FIG. 2. SPORES IN COOKED BEEF require much less heat treatment for sterilization after Co^{60} irradiation. Each No. 1 can of ground beef was inoculated with 300 spores of C. *botulinum* 213B (17)

process is equivalent if a tenfold change in spore-killing rate requires a change of 18° F. These are calculated from heat-penetration records of control cans.

Any of the processed cans that swell during incubation are considered incompletely sterilized. To confirm microbiological spoilage we open swollen cans, observe the odor of the gas for putrefaction, and prepare stained slides for microscopic examination. With *C. botulinum* some of the cans are also examined for toxin by mouse-inoculation tests. Processes are selected in such a way that at least one equivalent processing time value produces no swollen cans. Raw ground beef is processed similarly except that cans are sealed in a vacuum closing machine.

Figure 2 shows results with 300 *C. botulinum* spores per can of cooked beef; Fig. 3 is for 5,000,000 such spores in each can of raw meat. You will see that the F_0 for sterilization is reduced at least fourfold by 1.2 megarep.

The combined process is expected to require a larger sterilization F_0 with PA 3679 than with *C. botulinum* inoculation. Figure 4 shows data with 10,000 PA 3679 spores per can of cooked beef. The results are similar to those previously obtained with *C. botulinum* spores. In each instance the F_0 for sterile ground beef with 1.5 megarep of gamma radiation is not more than one fourth of that needed for heat processing alone.

Initial results with green peas appear to follow the same general pattern.

Significance

Varying sensitization of bacterial spores to lethal action of heat occurs when spores are preirradiated in media of different chemical composition. Therefore it can be anticipated that different foods will show different sensitizations and may, therefore, need different combined irradiation-heat processing schedules. Nevertheless irradiation of bacterial spores appears to be equally effective in raw and cooked ground beef for reducing the heat treatment subsequently required for sterilization.

If combined processing is applied industrially, irradiation and heat processing can be carried out independently at different places and different times. Since we have only been concerned with the microbiology involved in the combined process, we do not know whether the fourfold reduction in F_0 for sterilization that accompanies preirradiation with 1.3–1.5 of megaroentgens of gamma radiation is sufficient to be organoleptically, economically or otherwise significant in food processing.

Combination Process

Important microbiological features of combined irradiation-heat processing differentiate it from irradiation processing alone. For example, even an

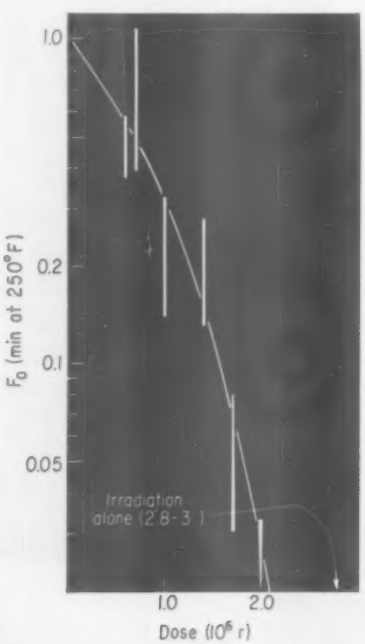


FIG. 3. SPORES IN RAW BEEF show same effect. Here 5 million C. *botulinum* spores went into the geometrical center of each can of ground beef (18)

Neutron Problem?

For monitoring, investigate the Eberline
FAST NEUTRON SCINTILLATION COUNTER,
Model SN-1A.

If you have a neutron problem,
perhaps Eberline knowledge and experience
in this field can be of service to you.

write to the attention of:
Don Mitchell

EBERLINE INSTRUMENT CORPORATION
Post Office Box 279 Santa Fe, New Mexico

Identification

THAT'S SURE, QUICK, SAFE

QUICK WIRE AND COMPONENT MARKING

Self-sticking markers for #8 to #28 wires. For component, prototype, production wiring. 2000 stock codes.

SURE PIPING SYSTEM IDENTIFICATION

Self-sticking markers tell pipe contents and flow. ASA-approved colors. Resist heat to 300° F. 350 stock legends. Specials made to order.

SAFE RADIATION HAZARD IDENTIFICATION

RADIATION HAZARD

Self-sticking signs mark unsafe conditions, areas. Meet AEC specs.

More information? Write for catalog 520 describing these, and 12 other Brady pressure-sensitive industrial products.

W. H. BRADY CO., 783 W. Glendale Ave. • Milwaukee 9, Wis.
Manufacturers of Quality Pressure-Sensitive Industrial Tape Products — Est. 1914 97

CENCO® HYVAC GAS BALLAST PUMPS

For vacuum applications plant and laboratory. Eliminates use of oil separators, centrifuges, refrigerated traps. Wide range of capacities.

For best possible results use Cenco pump oil. Write today for Bulletin 9C.

No. 91506-1 rated displacement, 70.0 liters per min....$284.25

cenco®

CENTRAL SCIENTIFIC CO.
A Subsidiary of Cenco Instruments Corporation
1736 Irving Park Road • Chicago 13, Illinois
Branches and Warehouses—Mountainside, N. J. Boston • Birmingham • Santa Clara • Los Angeles • Tulsa • Houston • Toronto • Montreal • Vancouver • Ottawa

an effective material for neutron shielding

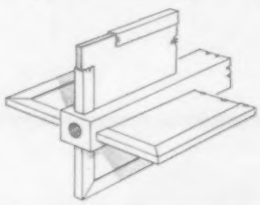
Boral is a uniform dispersion of boron carbide crystals in aluminum. Its high boron carbide content (up to 50%) enables it to absorb thermal neutrons without the production of hard gamma rays. In the form of Boral Plate (a core of Boral clad on two sides with commercially pure aluminum) it is highly effective as a neutron shielding material.

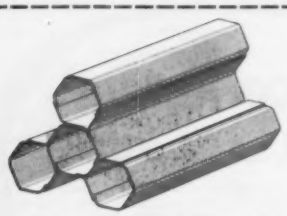
By following recommended design and fabricating practices, Boral Plate can be worked to meet the requirements of a wide range of shielding applications. It can be drilled, tapped, punched, sawed, sheared, formed, and welded. The accompanying sketches show typical designs and assembly methods.

Boral Plate is available in thicknesses of 1/16" to 3/4", and standard sheets of 30" x 48", 15" x 96", and 15" x 48". Approximate weight of 1/4" (35% B_4C) Boral Plate is 3.4 pounds.

Shut-down Control Rod for Reactors

Assembly of this unit is made by inert gas arc welding. As shown, all edges of Boral Plate should be clad. The center bar is tapped to receive the threaded rod.



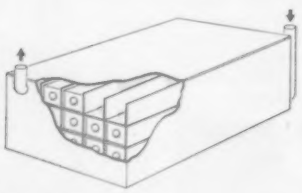


Storage Cells for Fresh Fuel

Cells are usually used in assemblies of several fuel units, encased in aluminum or stainless steel cylinders. The Boral shapes should have corner radii of 3/4"; length can be up to 12 feet. Assembly is by means of rivets or Huck bolts.

Water-cooled Boral-lined Case for Spent Fuel Elements

This Boral-lined aluminum case with egg-crate type separators for the transportation and storage of spent fuel units, is assembled from Boral Plate by arc welding; no forming operations are involved.



Typical and Potential Applications

Reactor shields, neutron curtains, shutters for thermal curtains, safety rods, storage and shipping containers for fissionable material, fabricated boxes for radiation-sensitve devices, protective shields for easily activated components.

Brooks & Perkins, the first commercial producer of Boral, invites you to send for technical data and literature. 60-T-4

BROOKS & PERKINS, INC.
1926 W. FORT STREET • DETROIT 16, MICHIGAN
Offices in Washington and New York

This article starts on page 108

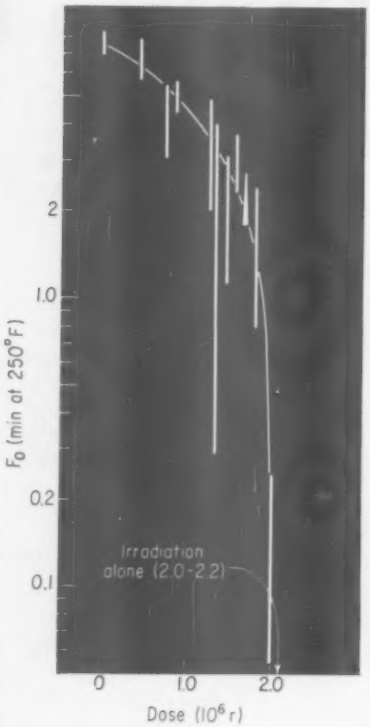


FIG. 4. PA 3679 SPORES also become more heat sensitive with Co^{60} exposure. Each No. 1 can of cooked ground beef was inoculated with 10,000 spores (18)

ionizing radiation dose of 4.5 megarads will not completely inactivate enzymes (*19*), certain micrococci (*20*) or botulinus toxin (*21*). On the other hand, micrococci, botulinus toxin (*22*) and all but a few enzymes are quickly destroyed by moist heat at 212° C. Furthermore even the relatively less intense combined process for canned meat containing 300 PA 3679 spores per can is much more severe than that necessary for ground beef containing 5,000,000 *C. botulinum* spores per can; following 1.3 megarads, PA 3679 has an F_0 of 1.5; 0.3 is enough for *C. botulinum*. Thus the safety factor due to the higher heat resistance of PA 3679 spores (compared to *C. botulinum*) in ordinary heat processing has also been found in the combined irradiation-heat process.

No matter how suitable any food processing treatment may be from a microbiological standpoint, its ultimate value depends on its economics, its effect on flavor, color and texture, or some specialized property such as utility in particular situations. Therefore it is desirable that combined

irradiation-heat processing be studied further from these viewpoints.

* * *

This paper reports research undertaken in cooperation with the Quartermaster Food and Container Institute for the Armed Forces, and has been assigned number 1030 in the series of papers approved for publication. The views or conclusions contained in this report are those of the authors. They are not to be construed as necessarily reflecting the views or endorsement of the Department of Defense.

BIBLIOGRAPHY

1. B. H. Morgan, J. M. Reed. Resistance of bacterial spores to gamma radiation, *Food Research* **19,** 357 (1954)
2. L. L. Kempe. Combined effect of heat and radiation in food sterilization, *Appl. Microbiol.* **3,** 346 (1955)
3. B. Kan, S. A. Goldblith, B. E. Proctor. Complimentary effects of heat and ionizing radiation, *Food Research* **22,** 509 (1957)
4. A. C. Giese, D. Heath. Sensitization to heat by X-ray, *J. Gen. Physiol.* **31,** 249 (1948)
5. E. C. Pollard. The combined effect of thermal and ionizing energy on viruses, in "Hepatitis Frontiers: Henry Ford Hospital International Symposium," pp. 355–370 (Little, Brown and Co., Boston, 1957)
6. W. T. Bovie, A. Klein. Sensitization to heat due to exposure to light of short wave lengths, *J. Gen. Physiol.* **1,** 331 (1919)
7. A. C. Giese, E. B. Crossman. The action spectrum of sensitization to heat with ultraviolet light, *J. Gen. Physiol.* **29,** 79 (1945)
8. H. R. Curran, F. R. Evans. Sensitizing bacterial spores to heat by exposing them to ultraviolet light, *J. Bacteriol.* **36,** 455 (1938)
9. A. C. Giese, E. B. Crossman. Sensitization of cells to heat by visible light in the presence of photo-dynamic dyes, *J. Gen. Physiol.* **29,** 193 (1946)
10. A. Hollaender. "Radiation Biology, Vol. 1: High Energy Radiation, Part I" (McGraw-Hill Book Co., New York, 1954)
11. H. Chick, C. J. Martin. On the heat coagulation of proteins, *J. Physiol.* **40,** 405 (1910)
12. W. T. Bovie. A preliminary note on the coagulation of proteins by ultra-violet light, *Science* **37,** 24 and 373 (1913)
13. S. Lewith. Ueber die Ursache der Widerstandsfaehigkeit der Sporen gegen hohe Temperaturen, *Arch. experimentelle Pathol. Pharmakol.* **26,** 341 (1890)
14. L. L. Kempe, J. T. Graikoski, R. A. Gillies. Gamma ray sterilization of canned meat previously inoculated with anaerobic bacterial spores, *Appl. Microbiol.* **2,** 330 (1954)
15. R. T. Jordan, L. L. Kempe. Inactivation of some animal viruses with gamma radiation from cobalt-60, *Proc. Soc. Exptl. Biol. Med.* **91,** 212 (1956)
16. J. G. Lewis, J. V. Nehemias, D. E. Harmer, J. J. Martin. Analysis of radiation fields of two gamma-radiation sources, NUCLEONICS **12,** No. 1, 40 (1954); R. H. Ellis, Jr., Gamma-irradiation facilities in the United States, NUCLEONICS **16,** No. 7, 188 (1958)
17. L. L. Kempe, J. T. Graikoski, P. F. Bonventre. Combined irradiation-heat processing of canned foods: I. Cooked ground beef inoculated with *Clostridium botulinum* spores, *Appl. Microbiol.* **5,** 292 (1957)
18. L. L. Kempe, J. T. Graikoski. Combined irradiation-heat processing of canned foods: II. Raw ground beef inoculated with *Clostridium botulinum* spores, *Appl. Microbiol.* **6,** 261 (1958); III. Cooked ground beef inoculated with spores of a putrefactive anaerobe, *Appl. Microbiol.* **7,** 133 (1959); IV. Green peas inoculated with anaerobic bacterial spores (in preparation)
19. R. S. Hannan. Scientific and technological problems involved in using ionizing radiations for the preservation of food (Special Report No. 61, Department of Scientific and Industrial Research, Her Majesty's Stationery Office, London, 1955)
20. A. W. Anderson, H. C. Nordan, R. F. Cain, G. Parrish, D. Duggan. Studies on a radio-resistant micrococcus, *Food Technol.* **10,** 575 (1956)
21. R. O. Wagenaar, G. M. Dack. Effect in surface ripened cheese of irradiation on spores and toxin of Clostridium botulinum types A and B, *Food Research* **21,** 226 (1956)
22. G. M. Dack, "Food Poisoning," (University of Chicago Press, Chicago, 1943)

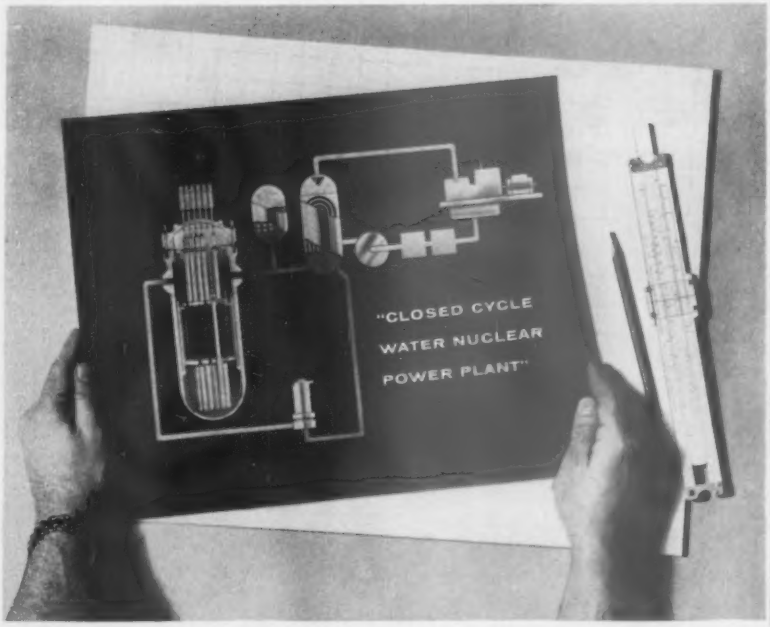
At Los Alamos, the mysteries of the universe provide the dynamics for projects ranging from space propulsion to nuclear research.

Original painting by Emil Bisttram, Taos, N. M.

For employment information write: Personnel Director Division 60-37

los alamos scientific laboratory
OF THE UNIVERSITY OF CALIFORNIA
LOS ALAMOS, NEW MEXICO

NEW PROFESSIONAL GROWTH OPPORTUNITIES for PHYSICISTS, SCIENTISTS, ENGINEERS, (Metallurgical, Chem., Mech.)



330-1 REACTOR—With a reactor vessel and closure head weighing 418 tons, standing 41 feet high and having a 12 foot ID, the engineers and scientists at the Commercial Atomic Power Department visualize a power system that can produce 360 gross electrical MW. This is the scope of planning now in progress at APD. You can take part in this or other phases of the rapidly expanding commercial nuclear power field where your talent can be applied to the problems of making nuclear energy competitive with other forms of power.

Scientist-Engineer—To plan, set up, perform and analyze critical experiments on light and heavy water reactors. Must have M.A. or M.S. or equivalent experience in nuclear physics or engineering.

Scientist-Engineer—To perform reactor physics design calculation and to solve advanced problems in reactor statics. M.S. degree in physics or engineering. Experience desirable, but not necessary.

Engineers—Materials development for fuel element prototypes including fabrication and testing of aluminum, zirconium and stainless steel alloys. B.S. degree in Metallurgy and preferably nuclear experience.

Engineers—Instrumentation and control section (a.) Analytical and design work on digital computer programs and techniques. M.S. or E.E. degree and several years experience. (b.) Development, design and application of neutron flux and radiation sensors and associated circuitry. Degree in electronics or physics with minimum of 4 years related experience.

Scientists and Engineers who want to make the transition to the expanding field of commercial atomic power with a company that is a leader in the field, write to: Mr. C. S. Southard, Westinghouse Atomic Power Division, P.O. Box 355, Dept. W-87, Pittsburgh 30, Pa.

Westinghouse

ATOMIC POWER DIVISION

FIRST IN ATOMIC POWER

that industry is fully capable of doing. Just what these are can be discovered best by experience and not by arbitrary decision. The number of developments that industry can take over effectively will grow, hopefully at a rapid rate. What we must keep in mind is that we are all interested in a national nuclear energy program, not a national laboratory program and industrial program as separate domains. The decisions for both must be based on what is best for the national program as a whole.

In its operations and in its recommendations to the Commission, Argonne National Laboratory has attempted, to the best of its ability, to comply with the above philosophy and it will continue to do so. Undoubtedly, we shall, from time to time, misjudge and make mistakes and so will industrial organizations, but that is inevitable in trying to make progress in a new field. I should like to stress that Argonne is as anxious to transfer activities to industry as is industry itself. Our backlog of research and development problems is such that we always endeavor to confine our attention to those which are clearly our responsibility and which exploit our special capabilities to the fullest.

Thank you again for the excellent editorial.

—Norman Hilberry, Director
Argonne National Laboratory
Lemont, Illinois

Well, Army . . . ?

Dear Sir:

Bully for Dr. Herman Kraybill's article in your January 1960 issue (p. 112) in which he casts well-deserved rocks at the pseudoscientific reasons for the reduction in the level of effort in the Army's radiation preservation of foods project.

Being somewhat of a pseudoscientist myself, and my husband having been associated with the project from 1954 to 1958, during which time we nibbled on gammafied goodies frequently, I made a number of biological observations that tend to belie some of the Army statements:

1. Although we were married in 1941, we had only one child, born in 1942, until we began to eat photonated foods. Since then we have had an isotot born in 1956, one in 1958 and now expect one in 1960. Sterility? Infertility? Hah!

If you are not subscribing to NUCLEONICS

- Use the handy card **below to place your subscription**
- YOUR OWN COPY INSURES UTMOST PERSONAL BENEFIT

Some Features of NUCLEONICS for 1960

1. Engineering of Reactor Cores and Primary Loops — updating current information on latest advances. A 24- or 32-page definitive report.
2. Exhibits and program of Atomic Exposition
3. How Radiation Affects Materials — a new look
4. Buyers' Guide (November)
5. Modern Tracer Techniques in Plant and Laboratory

SIMPLY MAIL COUPON BELOW

NOTHING TO PAY NOW
We will bill you after entry. Pay with order only if you prefer to do so.

NOTE TO PRESENT SUBSCRIBERS

This is not a notice for renewal if you are already subscribing. Card is intended only for new subscriptions. We shall appreciate your passing along this insert to one of your associates who might profitably subscribe.

NUCLEONICS, April, 1960

Enter my new NUCLEONICS subscription . . .

☐ FOR ONE YEAR, $8 ☐ FOR THREE YEARS, $16 (You save $8.)

_____SEND BILL LATER _____HERE'S THE MONEY

NU-

M-

4/60

Name: ..... Position.....

☐ Business Address:
☐ Home Address: .....

City: ..... Zone..... State.....

Company Name: .....
Nature of Nuclear Business
or Service .....

PLEASE PRINT

MAIL AT ONCE . . . to start service promptly.

Foreign Rates (1 year) Canada $10, Latin America $10, Other $15

*This Special Card**

is your new subscription invitation

Reflecting the startling growth of the publication's field, NUCLEONICS in a few short years has gained the enthusiastic support of over 20,000 subscribers in all parts of the world. We invite you to join them.

Your own copy of NUCLEONICS each month insures your being in close, prompt contact with what is new and important affecting Nuclear Research; Nuclear Technology; New Uses of Radiation in the Sciences and Industry; Radiation Protection; Radiation Waste Disposal; Health Physics, Instrumentation; Atomic Power Progress; Reactor Technology; New Materials; New Equipment; New Publications; International Commercial Alliances; Atomic Power Politics—the shifts and changes—the facts behind the news.

SEND NO MONEY - - - See other side for handy coupon

*** Please note that offer is for new subscriptions only.**

NUCLEONICS, April, 1960

FIRST CLASS
Permit No. 64
New York, N. Y.

BUSINESS REPLY MAIL
No Postage Stamp Necessary If Mailed in the United States

POSTAGE WILL BE PAID BY —

McGRAW-HILL PUBLISHING CO., Inc.

NUCLEONICS
330 WEST 42nd STREET
NEW YORK 36, N. Y.

2. On 7 January my husband donated his thirtieth pint of blood to a blood bank. He has never been turned down for any reason, including heart defect, hemorrhagic diathesis, or auricular rupture.

As a housewife I still believe that the three primary barriers to the acceptance of radiated rations are cost, the psychological factor and the changes in tastes, and *not* these other claims that Dr. Kraybill so ably refuted.

—MARY M. EVANS (Mrs. Belmont S.)
Bethesda, Md.

EDITOR'S NOTE: Lt. Colonel Belmont S. Evans, Jr., as indicated above by Mrs. Evans, had a four-year association with the Army food-irradiation program as Quartermaster Corps Liaison Officer to the AEC Office of Industrial Development. Our congratulations on the forthcoming blessed event.

Fast-Fuel Processing

DEAR SIR:

I found the reprocessing article in the November NUCLEONICS (p. 162, "Minimizing Fuel-Processing Costs") very interesting. I expect that APDA will adapt the technique for general use on fast-reactor studies.

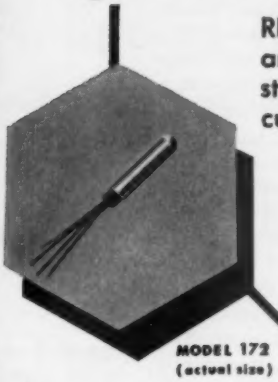
The article also stimulated several other ideas—at least one of which appears worthy of communication: "Combined reprocessing of Pu cores and depleted U blankets." The AEC conceptual reprocessing plant throughput rate is limited to approximately 31 kg/day of Pu^{239} and Pu^{241} (by criticality) and to approximately 1,000 kg/day of total heavy metal (by volume). For future fast reactors, fueled with Pu^{239} rather than U^{235}, the core will be so highly enriched (>15% Pu) that its reprocessing rate will be usually less than 200 kg/day. The blanket material, on the other hand, usually contains much less than 3.1% Pu. If the core and blanket are chemically compatible, their combined reprocessing will normally result in reductions of both actual processing charges and of cleanup (turn-around) charges.

If sufficiently high premiums are paid for high-quality Pu, the core and blanket would be processed separately. In this event, reprocessing savings might be achieved by processing the fast-reactor core with any chemically and isotopically compatible thermal-reactor cores or blankets.

—R. J. HENNIG, Engineer
Core Analysis & Test Section
Atomic Power Development Associates
Detroit, Michigan

Resistance Thermometers by REC.....

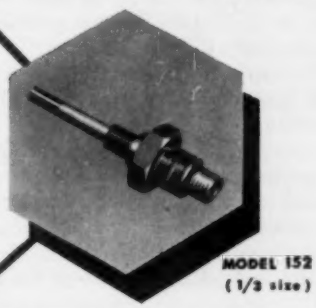
REC specializes in platinum resistance thermometers of exceptional stability and high calibration accuracy.



MODEL 172 (actual size)

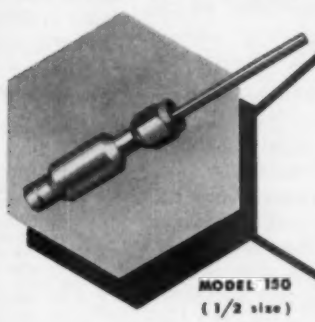
MODEL 172 series is a miniature element encased in a platinum-rhodium tube, useful from −260 to 750° C or up to 1100 C for short term use, and having a resistance of 100 ohms at 0° C, with other values available. It can be cemented or clamped to a surface, inserted in a hole, or molded into a body.

MODEL 152 probe features open platinum wire supported at intervals, resulting in extremely fast response and excellent thermal isolation between the element of the probe and the head of the probe. It is primarily intended for gases at moderate and low velocities, useful from −260 to +260° C or higher.



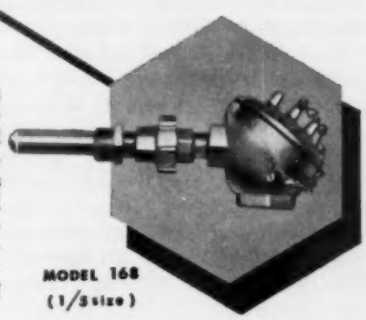
MODEL 152 (1/3 size)

MODEL 150 probe features a miniature element, only 0.160 OD outside the guard tube. It is useful from −260° C up, and finds wide applications in LO_2 and LH_2, and is available with various immersion lengths and is normally mounted by a flare fitting.



MODEL 150 (1/2 size)

MODEL 168A series probe uses a precision platinum resistance sensing element which is fully supported by a ceramic insulation. The element is protected by a stainless steel guard tube with additional support at the element tip for maximum protection to flow. The temperature range is +700° F to −435° F, and has a normal resistance of 1380 ohms at 0° C.



MODEL 168 (1/3 size)

Write for further information ....

REC

ROSEMOUNT ENGINEERING COMPANY

DEPT. MR-1

4900 West 78th St. Minneapolis 24, Minn.

We also make a wide variety of temperature probes for airplanes, missiles, rockets

(*Continued from page 70*)

phenomenon. Close to the nozzle exit, a high radial pressure gradient at the jet periphery creates diffusion and a resulting concentration gradient. With increasing axial distance d the effect of pressure diffusion decreases because of the decreasing pressure gradient, and, at the same time, a radial diffusion inward occurs because of the established concentration gradient and also because of the temperature gradient resulting from expansion. (The net thermal diffusion of the heavier gas is toward the low temperature region.) Becker, assuming an isentropic expansion, calculated that the thermal diffusion flow was about $\frac{1}{17}$ of the pressure diffusion flow for argon (*5*). Eerkens and Grossman estimate the ratio of thermal diffusion to pressure diffusion to be about 1/13.5 for an equal part molar He^4–A^{40} mixture (*10*).

The effect of varying θ shows that the jacket zones of the jet expand more rapidly than the core zone, which results in higher separation values for lower θ's (*4*). (Alternatively, one can say that the pressure gradient is steeper toward the jet periphery.)

Eerkens and Grossman at the University of California (*10*) have derived the fundamental steady-state diffusion equation and made a list of the experimental diffusion constants in connection with experiments on the separation of gaseous components in jets. A sample calculation of a typical separation in a jet for a molar mixture of He^4 and A^{40} indicated that pressure diffusion, concentration diffusion, and thermal diffusion occur in the proportions +0.135, −0.02, and −0.01, respectively (*10*).

Alternative Approaches

In further work, the California group (*7*) is investigating several other phenomena that might cause separation. These include separation of gaseous components inside plane and oblique shock waves; temperature, pressure, and concentration gradients in jets; and effusional behavior of molecular flow. The above mechanisms must be evaluated for slip flow conditions in a steady state jet, since Becker's experiments lie partly or wholly in the slip flow region (*7*).*

Recent work by Eerkens, et al in separating the components of air (*11*) shows a sharp localized decrease in the oxygen (heavier component) concentration in the diffuse shock inside the supersonic core (see Fig. 5). A pressure peak marks the position of depleted oxygen. In the experiment, gas samples were taken by a probe in the jet and pressure and concentration profiles were plotted axially and radially at several chamber pressures. In this work the pressures were an order of magnitude below those investigated by Becker while throat diameter was 0.875 in., about 200 times greater than those of Becker's studies.

Extrapolation of these results to uranium isotope separation indicates that it may be possible to obtain separation efficiencies at least 2 to 4 times higher than Becker's (*11*). The contention is that Becker, in his basic jet separation method, used a simple cone which divided the core of the jet from the fringe gas. He failed to investigate what happens when one sucks off annular portions of the jet. Thus his enriched gas fraction was a mixture of the highly separated annular shock region gas and all remaining gas in the surroundings. He thus diluted his high density, highly enriched shock gas with the low density, less enriched fringe gas.

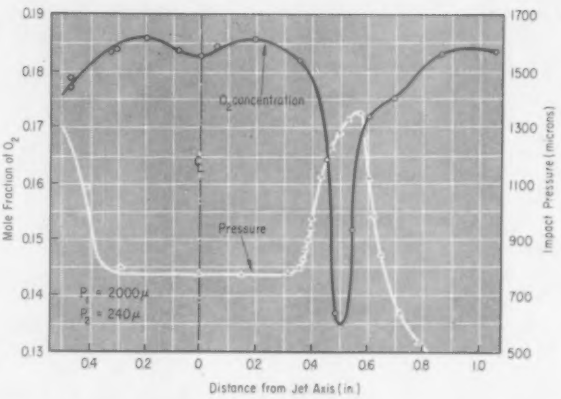


FIG. 5. JET PROFILE shows correlation between radial variations of jet pressure and O_2 concentration

However, reservations to this argument may be raised (*11*). First, extrapolating the data from air to UF_6 is somewhat uncertain. Second, Becker used extremely small diameter nozzles and may have had entirely boundary-layer type flow in his jets. It is difficult to predict whether this is worse or better than the partially supersonic core surrounded by a subsonic region in Eerken's work. The latter would seem to give higher radial pressure gradients (*11*).

Eerkens proposes also to study the enrichment of axisymmetrical or two-dimensional shocks caused by cores or wedges, in diffusers, or other objects.

BIBLIOGRAPHY

1. S. P. Dickens, C. A. Coghlan, P. G. Murrow, Separation of gases from mixtures thereof, U. S. Patent 2,607,439, July 28, 1948
2. E. W. Becker, K. Bier, The production of intense partially monochromatic hydrogen molecular beams with a Laval nozzle, *Zeitschrift fur Naturforschung* **9a**, 975 (1954)
3. E. W. Becker, K. Bier, H. Burghoff, The separating nozzle, a new apparatus for the separation of gases and isotopes, *Z. Naturforschung* **10a**, 565 (1955)
4. E. W. Becker, R. Schutte, The separation of uranium isotopes with the separation nozzle, *Z. Naturforschung* **11a**, 679 (1956)
5. E. W. Becker, W. Beyrich, K. Bier, H. Burghoff, F. Zigan, Isotope separation by the strip-nozzle method, Part II. Physical principles of the separation effect and the specific efforts of this method, *Z. Naturforschung* **12a**, 609 (1957)
6. E. W. Becker, Enrichment of the light uranium isotope by means of the diffusion process, *Chemie-Ingenieur Technik*, Nr. 6, 365 (1957)
7. J. W. Eerkens, Design considerations and region of operation of the jet diffusion equipment, University of California, HE-150-158, July 8, 1957
8. G. Nardelli, A. Repani, Physical principles of the trennduse method, *Energia Nucleare* **4**, No. 4, 293 (1957); English translation by B. Rigby, U. K. Atomic Energy Authority, IGRL-T/R-61 (1959)
9. V. Fillipenko, Mathematical formulation of the one-dimensionalized dynamics of a diffusing binary gas, University of California, HE-150-151, December 5, 1957
10. J. W. Eerkens, L. M. Grossman, Evaluation of the diffusion equation and tabulation of experimental gaseous diffusion constants, University of California, HE-150-150, December 5, 1957
11. J. W. Eerkens, B. Sehgal, L. Grossman, Some preliminary results on the separation of gaseous components in a jet, University of California, HE-150-162, June 4, 1958
12. E. W. Becker, K. Bier, H. Burghoff, O. Hagena, P. Lohse, R. Schutte, P. Turowski, F. Zigan, Separation of the uranium isotopes by the nozzle process, Second U. N. Conference on Atomic Energy, A/Conf No. 15/P/1002, Federal Republic of Germany, August 4, 1958
13. K. Cohen, "The Theory of Isotope Separation as Applied to the Large-Scale Production of U^{235}" (McGraw-Hill Book Co., Inc., New York, 1949)
14. M. Benedict, T. Pigford, "Nuclear Chemical Engineering" (McGraw-Hill Book Co., New York, 1957)
15. S. Chapman, T. G. Cowling, "The Mathematical Theory of Non-Uniform Gases," 2nd ed. (Cambridge University Press, New York, 1952)
16. M. D. Rousso, F. D. Koschendorfer, Velocity and temperature fields in circular jet expanding from choked nozzle into quiescent air, NACA RM E51F18 (July 1951)

* Slip flow occurs for gas molecules with mean free paths which are an appreciable fraction of the orifice diameter.

ADVERTISEMENT

FORD INSTRUMENT CO.

nuclear news

Published periodically to report Ford Instrument progress and capabilities in the nuclear field

New Digital Method of Reactor Instrumentation

A completely new method of measuring important nuclear reactor variables with direct digital sensing and readout has been devised by Ford Instrument Company.

Primary advantage is that it provides a discrete measurement which does not vary with ambient temperature, line voltage, and line frequency.

Digital output may be fed directly to an indicating register or may be supplied as data input to a digital computer. The method is highly applicable to measurement of reactor control-rod position and of liquid level in reactor pressure vessels.

Study Shows Thermionic Power Close at Hand

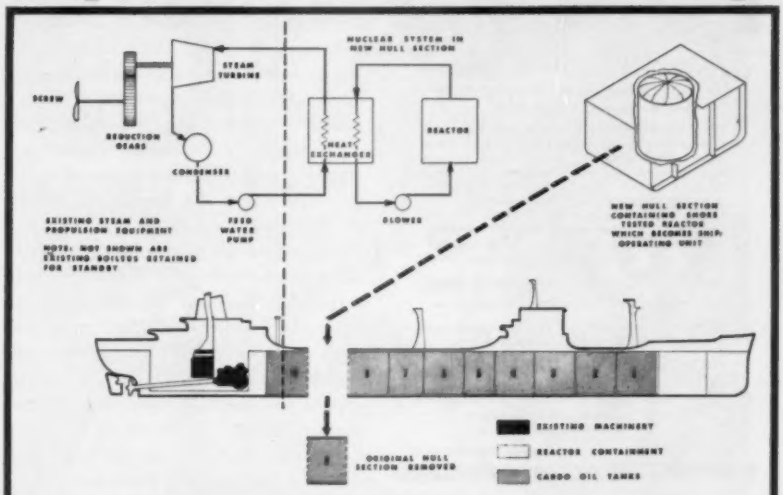
Ford Instrument engineer checks electrical output from thermionic converter in oven at right.

Thermionic studies, now under way in Ford Instrument laboratories, indicate that a vast new field for power generation is being opened up. First generation model thermionic cells (for direct conversion of heat into electricity) have been built, including units which provide surprisingly high current densities at moderate temperatures.

Ford Instrument thermionic studies include the feasibility of building thermionic converters into the fuel elements of nuclear reactors, the use of fossil fuels and solar energy for thermionic conversion, and construction, study and evaluation of numerous thermionic cell types.

HELP WANTED, ADVANCED THERMIONICS: Ford Instrument's growing activities in thermionics have created openings for work in this advanced new field.

Economical Nuclear Conversion Proposed for U.S. Merchant Ships



Conversion method developed for *S. S. Hans Isbrandtsen*-type tanker eliminates separate land-based prototype reactor.

The conversion of conventionally powered merchant vessels to first-of-kind nuclear propulsive power is not only feasible but may offer a powerful new technique for speeding up the over-all development cycle of the U.S. Nuclear Merchant Marine.

That's the principal conclusion of a study recently completed for the Maritime Administration by Ford Instrument, jointly with Maryland Shipbuilding and Drydock Company, and Isbrandtsen Company.

The proposed plan allows use of the same reactor as both land-based prototype and operating unit. (See illustration.) This eliminates the usual high cost and long delay inherent in constructing and testing of a land-based prototype, followed by a second, nearly identical unit, for operational use.

The graphite-moderated, helium-cooled reactor, generating steam at 950F., allows use of the ship's existing propulsion machinery without modification.

FALLOUT "ISODOSES" PREDICTABLE BY ELECTRONIC MEANS

A study program, just completed by Ford Instrument for the U.S. Army Signal Corps, shows that fallout patterns due to nuclear bursts can be predicted, using a mathematical model.

The ultimate objective is the utilization of this model as the mathematical basis for a high-speed electronic "predictor" which would display fallout areas by lines of equal radiation intensity, or isodoses. Such a predictor would have important military and civil defense applications.

Ford Instrument weapons capabilities include missile guidance and control, fuzing devices, and many other computer and control systems. O.1

For complete details on Ford Instrument's nuclear capabilities and services, write: Nuclear Sales, Ford Instrument Co., 31-10 Thomson Ave., Long Island City 1, N.Y.

FORD INSTRUMENT CO.
DIVISION OF SPERRY RAND CORPORATION

A CREATIVE TEAM OF SCIENTIFIC, ENGINEERING AND PRODUCTION TALENT

PROPIPETTE
Safety Pipette Filler
holds liquids indefinitely

• Time Tested • No moving parts
• Simple to operate

The new PROPIPETTE eliminates the dangerous practice of using the mouth to draw liquids into pipettes. It is simple to use and the operator soon becomes proficient so that liquids can be delivered quickly, precisely and safely. Measurement precision is extremely high (0.01cc). The instrument has three agate-ball valves which operate independently and the entire procedure can be done with only one hand.

PRICE $6.90 each . . . comes in black, red, green and blue, sent on approval.

all laboratory pipettes can be used with the PROPIPETTE—Safety Pipette Filler.

Write for additional information

INSTRUMENTATION ASSOCIATES
Distributors of Laboratory and Scientific Specialties
17 West 60th Street New York 23, N.Y.

NEW! BENDIX
200mr
DOSIMETER

★ MEASURES INTEGRATED EXPOSURES TO X AND GAMMA RAYS

★ APPROVED FOR MATCHING FUND PROCUREMENT BY OCDM

Product of famous Bendix precision craftsmanship, this 200mr Dosimeter offers the utmost quality and reliability. Weighs less than 1½ ounces. Only 4⅛" long and 1⅞2" in diameter. Highly shock resistance. Write BENDIX AVIATION CORP., Dept. G-4, 3130 Wasson Road, Cincinnati 8, Ohio.

Cincinnati Division
Cincinnati, Ohio

Bendix

Canadian Sales: Computing Devices of Canada, Ltd., Box 508, Ottawa 4, Ontario. Export Sales: Bendix International, 205 E. 42nd Street, New York 17, N.Y.

BOOKS

Radiation Hygiene Handbook

Edited by HANSON BLATZ (McGraw-Hill Book Co., New York, 1959, 926 pages, $27.50)

Reviewed by E. E. ANDERSON, Oak Ridge National Laboratory, Oak Ridge, Tenn.

As Hanson Blatz states in the preface of this book, this is the first handbook in the field of radiation hygiene or health physics. Mr. Blatz and McGraw-Hill are to be congratulated upon having performed a truly formidable task. One is pleased to see such an impressive list of distinguished contributors.

As is perhaps true of all handbooks, and particularly the first to appear in a relatively new field, it leaves much to be desired to make it a completely useful and truly useable handbook. This reviewer constantly felt the lack of coordination between the contributors as well as the lack of a clear objective in compiling the book; i.e., for whom is the book compiled. The experienced Health Physicist will find it of value, yet much of the material is too elementary for his use. Portions of it will be of considerable value to the beginner, but other sections will leave him in the dark. For example, detailed discussion is provided on how counters operate, but discussion of the calibration of these instruments is completely lacking. Some sections could well be part of a textbook on health physics while others meet this reviewer's idea of a section for a handbook as this claims to be. For instance, Sections 7, 8, 14, and 16 have a wealth of material that the health physicist will be happy to find assembled in one place and in a form easy to use. In these sections the form is that of a handbook.

Sections 11 and 12 are excellent chapters in themselves and beginners in the field will find in them much of value. However, in the reviewer's opinion a more logical approach would have been a section devoted first to the fundamental principles of radiation protection which apply in all situations where radiation hazards are present, followed by discussions of those problems unique to industrial operations and to research establishments.

Perhaps the most severe criticism of the book is the failure in several instances to make use of the most up-to-date information in the field.

I refer particularly to section 6 (Radioactive Isotopes and Their Properties) and to Table 3-3, Maximum Permissible Amounts of Radioisotopes in Total Body and Maximum Permissible Concentrations in Air and Water. In the compilation in section 6 no reference is made to a revision of the principal work on which the compilation was based, that of Hollander, Perlman and Seaborg which appeared in 1958; nor to the work of the Nuclear Data Group of the National Research Council.

In Table 3-3, the values given are taken from Handbook 52 published in 1953, while the ICRP report of 1954 (published in 1955 as Supplement No. 6 British Journal of Radiology) gives values which in many cases differ greatly from the earlier ones, and the new NCRP and ICRP compilation of 1959 gives the most recent values. For example, F^{18} concentration in air is quoted as 1×10^{-4} μc/ml, the 1954 value was 3×10^{-5} μc/ml, and the new value is 2×10^{-6} μc/ml. For permissible level of F^{18} in water, the old value is 0.9 μc/ml, in 1955 it was 0.2 μc/ml, and the new value is 8×10^{-3} μc/ml.

Perhaps this points up the difficulty of quoting values in a field which is changing rapidly. However, the reviewer believes that the 1954 ICRP values should have been given. The 1959 values were not yet available when the book went to press.

On page 3-30 a *serious* typographical error occurs. Note c. gives limits in mc/ml rather than μc/ml.

A few comments on section 1, Reference Data. The reviewer believes that much of this is waste space in a volume already too large and expensive. Logarithm tables and other mathematical tables are to be found in many other books physically much easier to handle. In the glossary of terms, the reviewer would prefer a more carefully selected group of terms, more fully explained and carefully defined. There exists in Handbook 62 a clear and explicit definition of absorbed dose, which should have been used. Missing fron the glossary are two terms of considerable value to the health physicist,—"mass stopping power" and "linear energy transfer." In Table 1–4, b is used as the symbol for the buildup factor, yet in Sections 8 and 14, the symbol used is B. In a compilation by different contributors it might have been wiser to dispense with Table 1–4.

In spite of the above criticisms, there can be no doubt but that the book will be widely used. The reviewer realizes

the magnitude and difficulties of the task undertaken and appreciates the very great need the book fills.

EDITOR'S NOTE: Dr. Anderson's review was submitted to Mr. Blatz, editor of the handbook, for comment. His remarks follow:

The figures in the table of isotope properties had all been brought up to date at the time of going to press and were essentially identical to the two sources Dr. Anderson suggests that we should have used. We gave credit to the authors of the original compilation and arrangement since it was the only such complete table in print at press time.

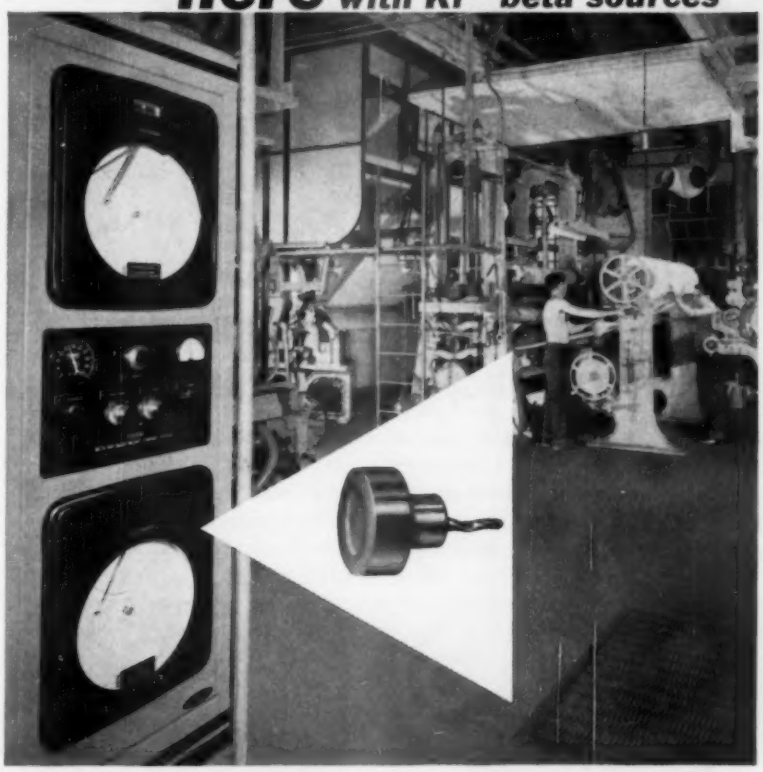
The maximum permissible concentrations were the accepted values then and for the most part were still appearing in legal codes and regulations (including those of the AEC). We chose to use them rather than the latest committee recommendations because of our expected audience, which should include a high percentage of administrators, lawyers and government workers. Scientists should not resort to handbooks for the latest committee recommendations.

The "serious" typographical error was in a section on Codes and Regulations and a direct quote (including error) from a Bureau of Standards handbook. It is a footnoted alternative value given in a large table of values suggested for a model code and had appeared in several state codes. It does, however, appear to be an unreasonable value.

The definitions in the glossary were mostly from the report of a committee of the National Academy of Sciences. Special permission was obtained for their use since it is believed that they have wide acceptance in the scientific community.

The Industrial Challenge of Nuclear Energy, proceedings of the Stresa Conference (May 1959) on Industrial Prospects in Nuclear Energy, in 4 volumes (Organization for European Economic Cooperation, Paris, 1959–60, $3 per volume). 500 nuclear leaders discussed the industry's prospects in Europe. Part One surveys European programs and economics of nuclear power; Part Two is on atomic law and administration; Part Three on the market for nuclear materials; Part Four on the market for nuclear equipment.

control starts here with Kr^{85} beta sources



Regulation of basis weight by means of a beta gaging system is the key to product uniformity in this large paper plant. Control unit manufactured by The Foxboro Company utilizes a krypton-85 beta source from United States Radium Corporation—largest producer of radiation sources in this country.

This installation is one of thousands using beta, gamma and neutron sources fabricated by U. S. Radium. It is typical of the many current applications of Kr^{85} beta sources of linear or point-type design with concentrations of a few microcuries to a curie or more.

Beta sources, now available in a wide range of configurations, intensities and energies, include Kr^{85}, H^3, C^{14}, Ni^{63}, Pm^{147}, Tl^{204}, Sr^{90}, and Ru^{106}, among others. Gamma sources incorporating natural or artificially-produced isotopes include Ra^{226}, Co^{60}, and Cs^{137}, all designed to specification. Neutron sources, calibrated or uncalibrated, are available in radium-beryllium, radium D-beryllium, polonium-beryllium and actinium-beryllium.

U. S. Radium will consult on design of beta, gamma and neutron sources to meet your own requirements. Write Department F4.

To keep pace with our expansion, U. S. Radium is continually seeking trained technical personnel. Please address inquiries to Director of Personnel.

UNITED STATES RADIUM CORPORATION

MORRISTOWN, N. J. | Offices: Chicago, Illinois and North Hollywood, Calif. Subsidiaries: Radelin Ltd., Port Credit, Ont., Canada and U.S. Radium Corp. (Europe), Geneva, Switzerland.

was calculated using a fission-neutron energy spectrum, neutron-absorption cross sections and an absorption model that mocked up a cross-sectional view of the fission-plate assembly in slab geometry of infinite extent. A simplified method of calculating fast-neutron albedos indicated that neutron leakage from the tank is approximately compensated for by fast neutrons scattering into the tank from surrounding media. Hence P_2 is essentially unity. Evaluation of the SP-2 fission rate by the neutron-emission method is summarized in the table, where the factor 2 accounts for the fact that only half the neutrons are emitted towards the tank.

3. Comparative heat generation rates. A third estimate for SP-2 power was obtained by comparing the heating rates for a known electrical power input into the SP-2 assembly to the heating rate produced by fission. Electrical input was by means of heating coils embedded in the SP-2 assembly frame and fed through the electrical lead-in tube shown in Fig. 2. Power input was determined from current and voltage drop measurements through the heater windings. Resistance-type temperature gages, attached to the surface of SP-2 and connected to a Wheatstone bridge through the electrical lead-in tube, were used to follow the temperature response.

Because the boral shutter between the SP-2 assembly and the graphite reactor was open only when performing fission-power runs, the heat-transfer mechanisms for electrical and fission-power dissipation were not identical. Thus a realistic estimate of the fission power level was obtainable only by extrapolation to zero heating time.

The estimated heating power had to be further corrected for the fission neutrons and gamma rays that escape from the fission-plate assembly and thus do not affect plate temperature. Fission energy absorbed in the source plate was summed as in the table and the fission rate obtained by conversion of estimated wattage to fissions per second.

SP-2 Source Strength

A weighted average of the three calibration methods gives a fission rate of $1.62 \times 10^{11} \pm 5\%$ fiss/sec (where the weighting factors were determined by the inverse square of the absolute

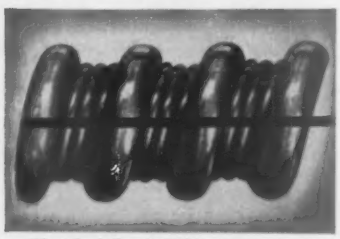
BEHIND THE TELEFLEX APPROACH:

A NEW TECHNIQUE FOR REMOTE POSITIONING, REMOTE CONTROL!

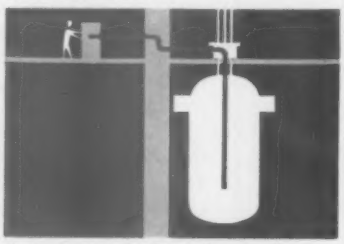
The TELEFLEX principle using unique helical cable gives new freedom in designing systems for remote operation or control in reactors. You can obtain extremely critical measurements, or position radioactive elements with precision and dependability. You can perform mechanical action in remote locations without costly downtime or personal hazard . . . at minimum cost. Here are a few of the advantages of TELEFLEX Systems . . .

Helix wire of cable engages specially hobbed wheel to drive cable in *tension and compression*, continuously, over long distances.

Cable and rigid conduit can be formed to meet any physical characteristics of reactor design, will fit in or around existing structures.



Electrical Lead Cable transmits electrical signals through insulated wires stranded in cable core—eliminates external electrical wires. Thermocouples, electro-magnets, ion-chambers are easily moved and replaced.



Actuator can be located away from radiation areas permitting use of standard commercial components. Systems operate in temperature extremes to 1400°F. Maintenance is practically eliminated, only periodic inspection is necessary.

Depth of experience with unusual control applications allows TELEFLEX engineers to analyze your control problem with a completely unrestricted viewpoint. To see how the "TELEFLEX Approach" can help you, send today for full information.

TELEFLEX®
INCORPORATED NORTH WALES, PENNSYLVANIA

error). If one assumes an absolute energy release of 200 Mev/fiss, then SP-2 is equivalent to 5.18 ± 5% watts of reactor power. Since shield designers are concerned with penetrating high-energy radiations, calculations were made to obtain the "effective radiation leakage" from the fission-plate assembly of 0.88 for gammas and 0.94 for neutrons.

SP-1 Source Strength

Since SP-1 data is in wide use, the "effective source strength" of SP-1 was re-evaluated and found to be 1.7 ± 11% watts for neutrons and 1.14 ± 20% for gammas (*4*). The SP-1 effective source strength was evaluated from the known source strength and "effective radiation" leakage of SP-2 and the relative neutron and gamma levels in the LTSF from SP-1 and SP-2.

The large difference in the effective power of SP-1 for neutrons and gammas is attributed to excessive self-absorption of gammas by the thick SP-1 components. In addition, a larger error is associated with the estimated effective power of SP-1 for gammas by a contribution, of uncertain magnitude, from secondary gammas that result from neutron capture in the LTSF water.

Weighted Average Effective Source Strengths of LTSF Fission Plates

SP-1:

1.7 watts for neutrons

1.14 watts for gammas

SP-2:

4.87 watts for neutrons

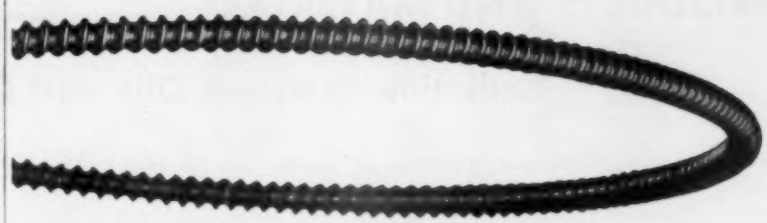
4.56 watts for gammas

* * *

These experiments were performed at the LTSF while the authors were on loan to the Oak Ridge National Laboratory. The authors express their thanks to R. W. Peelle, J. M. Miller, W. R. Burrus, and J. R. Smolen for their contributions to this paper and to J. R. Taylor, E. B. Beckham, H. R. Hendrix, B. M. Millican, and H. J. Jarvis for help in data assimilation.

BIBLIOGRAPHY

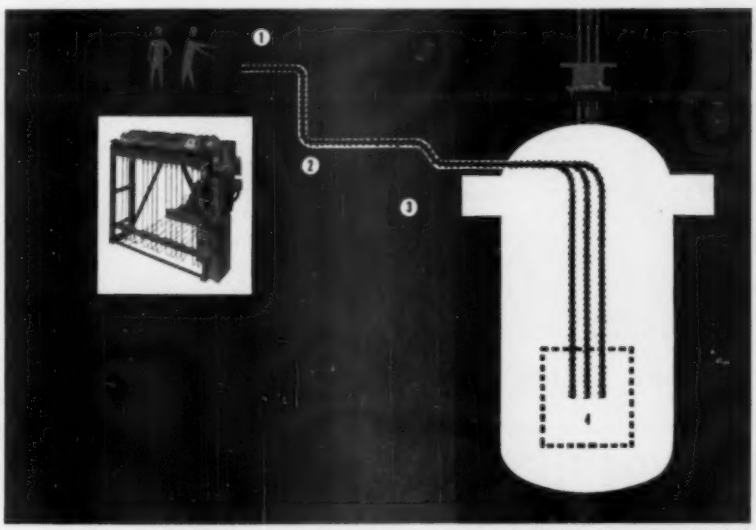
1. S. Glasstone, "Principles of Nuclear Reactor Engineering," (D. Van Nostrand Co., Inc., Princeton, N. J., 1955)
2. D. J. Hughes, J. A. Harvey. Neutron cross sections, BNL-325 (1955)
3. E. Fermi, *Revs. Mod. Phys.* **9**, 132 (1937)
4. J. Smolen. Determination of the effective power of the old source plate (SP-1), paper 40, ORNL-2081 (1956)



WITH THE TELEFLEX APPROACH:

A NEW TECHNIQUE FOR DETERMINING FLUX MEASUREMENTS AND FUEL BURN-UP "IN CORE"

This TELEFLEX development—called the Activation Wire Drive—permits you to position flux wires, thermopiles or ion chambers in a reactor core—with high accuracy, over distances up to 100 feet or more. The required detecting elements are attached to the end of TELEFLEX Cable and are driven through "thimbles" into the pressure vessel. The Cables are driven at speeds up to two feet per second and are positioned "in core" within ±¼ in. Insertions can be made at any time for any desired time interval.



TELEFLEX Activation Wire Drive (1) drives cable through "thimbles" (2) which penetrate biological shielding (3), into reactor core (4). After exposure, detectors are withdrawn to storage area.

TELEFLEX electrical lead cables provide a continuous signal from ion chamber and thermopile without additional wiring. This is just one example of the "TELEFLEX Approach" applied to an existing problem. Other completely developed systems include control rod drives, source drives, valve controls, special mechanisms. Write for TELEFLEX Nuclear Catalog, or send specifications for a detailed recommendation.

TELEFLEX®
INCORPORATED NORTH WALES, PENNSYLVANIA

PRODUCTS AND MATERIALS

Radiation-Resistant Oils and Greases

A complete line of radiation-resistant oils and greases now available is outlined in the table below. The lubricants are made from alkyl aromatic-type base oils and contain special additives. Two figures at right show radiation stability of the lubricants and their ability to retain good physical properties such as fluid range and lubricity when irradiated with gamma rays or a mixture of neutrons and gamma rays to doses substantially in excess of 10^9 r. This behavior, combined with the wide range of formulations, suggests application in a variety of radiation situations.—Standard Oil Co. of California, 225 Bush St., San Francisco 20, Calif.

Product	Dose Limit (10^9 r)	Application
	OILS	
NRRO 358 (light)	5	Hydraulic and accessory equipment to 225° F
NRRO 359 (medium)	5	Gears and accessory equipment to 225° F
NRRO 360 (heavy)	5	Conveyors, gears and accessory equipment to 225° F
NRRO 216	2.5	Hydraulic pumps and accessories at 3,000 psi; 300° F bulk, 600° F hot spots
NRRO	2.5	Engines, gears, bearings; 300° F bulk, 700° F hot spots
Chevron OC Turbine	0.1	Stationary turbines to 225° F
Chevron Insulating	0.1	Transformers, switchgear to 225° F
Chevron Gear Compound	0.1	Conveyor and equipment in hot cells to 200° F
	GREASES	
NRRG 335	5	Bearings, actuators up to 200° F
NRRG 300	5	Bearings, actuators up to 200° F
NRRG 235	5	Low-speed high-load sliding surfaces to 200° F
NRRG 159	2.5	Ball bearings, motors, pumps to 350° F
Chevron Industrial	0.25	Ball bearings, motors, pumps to 300° F
Chevron OHT	0.25	Ball bearings, motors, pumps to 300° F

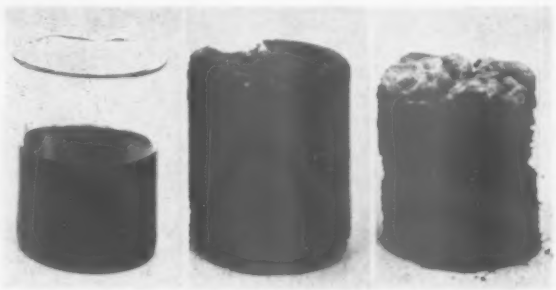


FIG. 1. GAMMA-IRRADIATED OILS. Equal quantities of three lubricating oils received doses of 4.4 × 10^9 r of gamma irradiation. NRRO 358 (left) shows no degradation, but hydraulic fluid mineral oil (center) and turbine lubricant mineral oil (right) have expanded and solidified

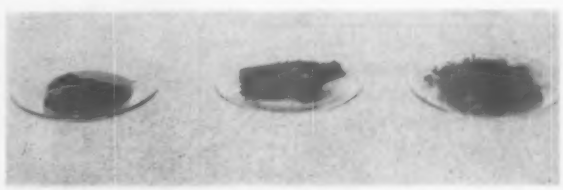
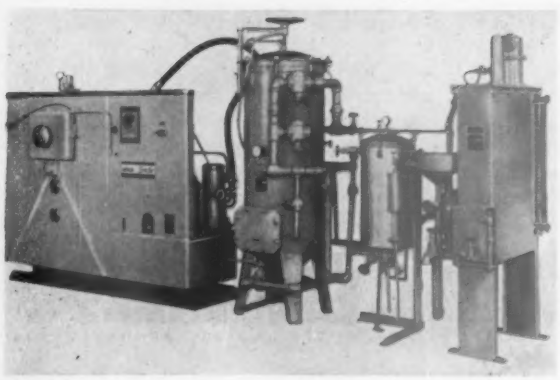
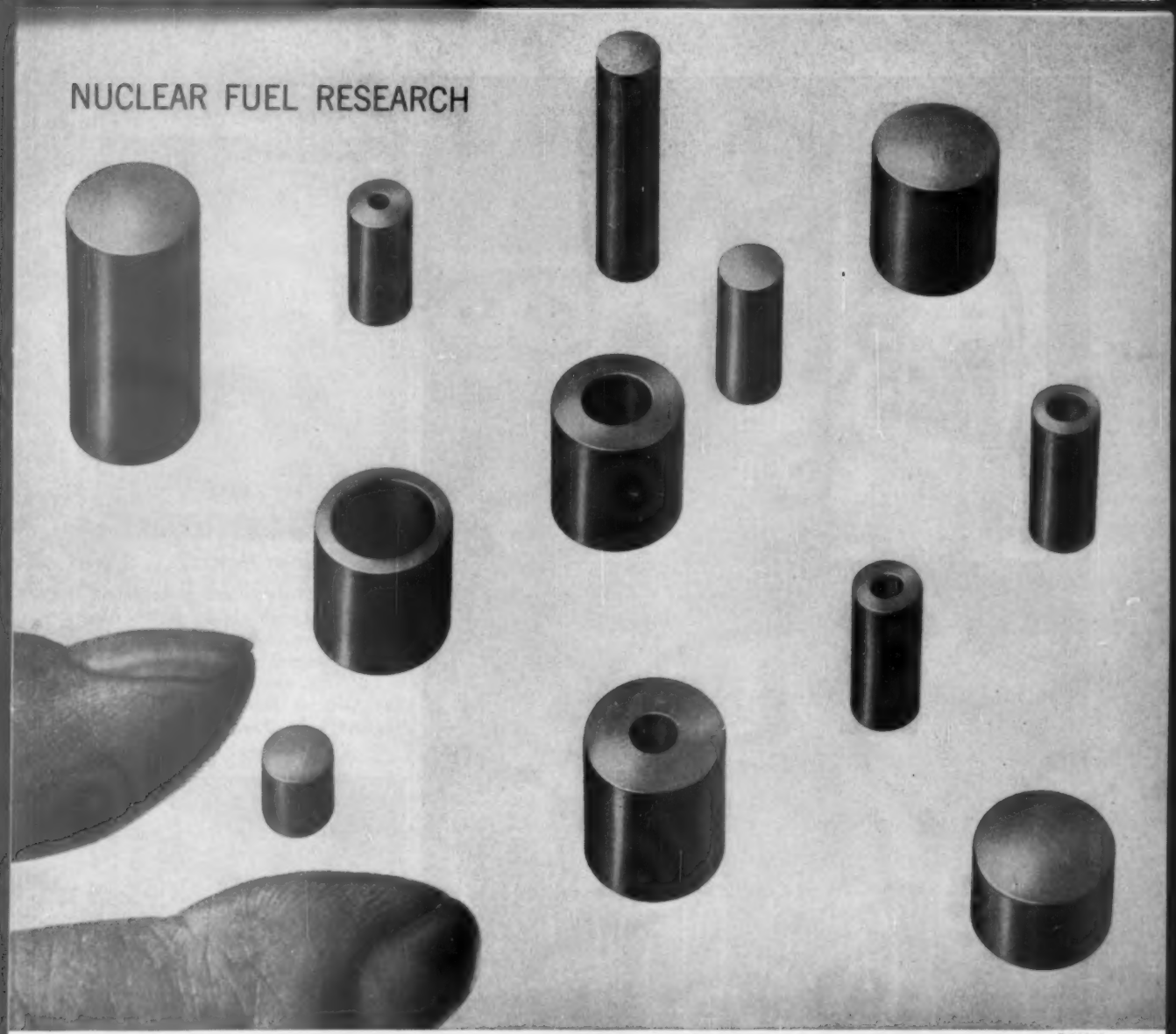


FIG. 2. REACTOR-IRRADIATED GREASES. Equal quantities of three greases received equivalent of 4.6 × 10^9 r in the Materials Testing Reactor. NRRG 300 (left) shows no degradation, but MIL-G-3278 (center) and MIL-G-3545 (right) greases have expanded and solidified



Contaminated-Glove Cleaner

Leather-palm work gloves contaminated with natural uranium are dry-cleaned with modified standard dry-cleaning equipment (left). The system uses perchlorethylene solvent and a tubular-type filter with capacity of 3,000 gal/hr for continuous filtration of solvent. Uranium residue is easily recovered from filter with sludge-accumulator stripper. Feed Materials Production Center, Fernald, Ohio, can clean 600 pairs of gloves per day with the system. Radioactivity is reduced to <10% of precleaning level.—American Laundry Machinery Co., Cincinnati 12, Ohio.



J-58002

FROM WESTINGHOUSE . . . HIGH-EFFICIENCY, LOW-COST FUEL FOR INDUSTRY

Solid, hollow core, and annular pellets and oxide wafers are being produced and tested for heat efficiency and ease of manufacture at the new manufacturing development laboratory at Westinghouse Atomic Fuel Department.

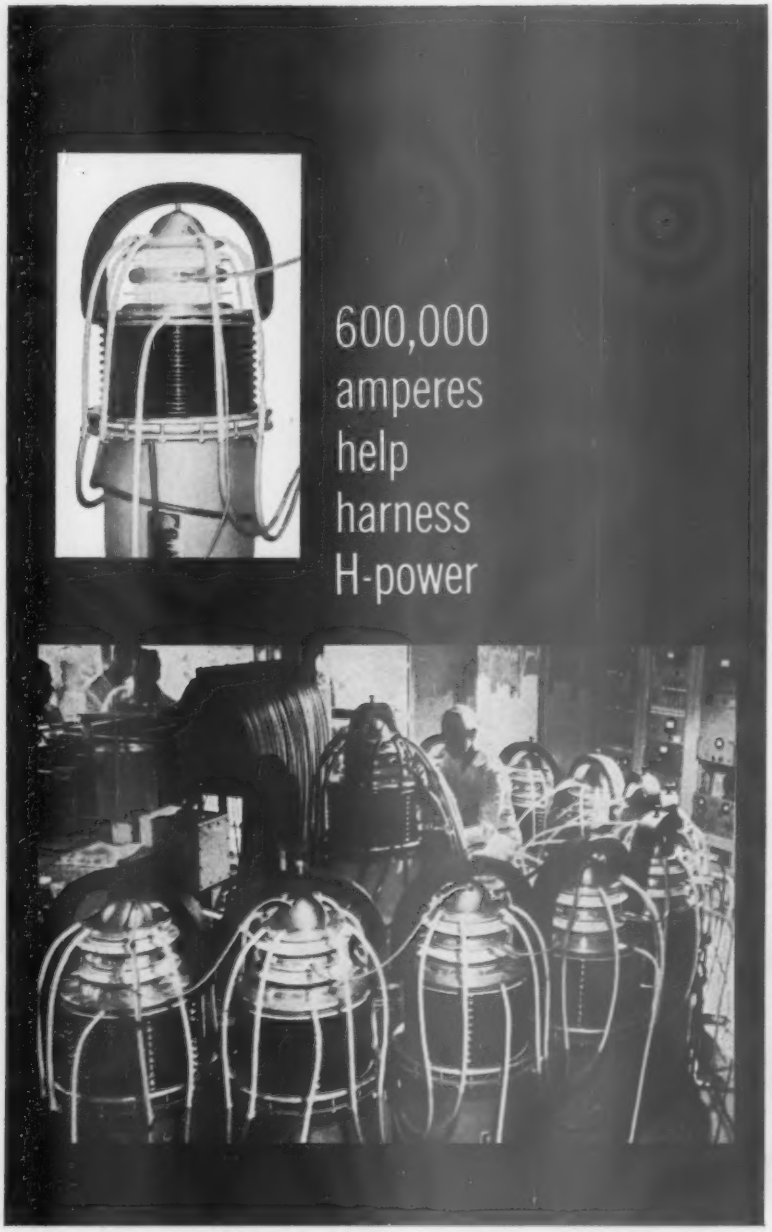
This complete fuel service facility is devoting its major effort to evaluation and improvement of dimensional tolerances and over-all quality of fuels in all shapes. It is capable of producing economically any size run of pellets from a dozen to hundreds of thousands. And, with its complete versatility, it is able to shift from one blend or enrichment to another within two or three hours.

For evaluation of fuel design, manufacturability, and for production of standard or new fuel forms, take advantage of these complete, versatile manufacturing development and processing facilities for: cored and annular pellets; continuous strip compacted fuel blends; zircaloy brazing; swaging; aluminum induction brazing, etc. Our extensive experience includes fabricating and handling of UO_2, cermet and alloy fuels, and zirconium, niobium, molybdenum, aluminum, stainless and other cladding and control materials.

Atomic Fuel Department, Westinghouse Electric Corporation, P. O. Box 217, Cheswick, Pennsylvania.

YOU CAN BE SURE...IF IT'S Westinghouse

WATCH "WESTINGHOUSE LUCILLE BALL-DESI ARNAZ SHOWS" CBS TV ALTERNATE FRIDAYS



At the historic Geneva Atoms-For-Peace Conference, Los Alamos scientists unveiled Scylla—a fusion device used to heat a plasma of ionized heavy hydrogen particles millions of degrees by blasting it with a 600,000-ampere thunderbolt.

Surrounding the heart of this thermonuclear machine is a bank of Tobe low-inductance, energy-storage capacitors...each rated at 100,000 volts, each capable of a 20,000 megawatt peak surge.

Why Tobe capacitors? Because only Tobe, with over 30 years of capacitor experience, could meet the rigid design specifications set for the project. Tobe capacitors can meet yours, too. We invite inquiries for a single energy storage capacitor or a complete energy storage system including capacitors, racks, interconnecting lines, protective devices and charging power supply.

For further technical information or engineering aid, write to Cornell-Dubilier Electric Corp., Marketing Office, Norwood, Mass.

CDE **CORNELL-DUBILIER ELECTRIC CORPORATION**
Affiliated with **Federal Pacific Electric Company**

PRODUCTS & MATERIALS

Department starts on page 124

Gas-Circulator Motors

Hunterston Nuclear Generating Station will use 16 gas-circulating motors like the two shown above. The 1,230-v d-c double-armature-type motors operate at 1,040 rpm and develop 2,354 hp.—The General Electric Co. Ltd. of England, Erith, Kent, England.

Stainless-Steel Outlet Header

Outlet header (above) for Plutonium Recycle Test Reactor is made of 10¾-in.-o.d. type 304 stainless steel with 0.75-in.-thick walls. Ninety 1½-in. outlets for water cooling lines were welded to ring.—Dravo Corp., Neville Island, Pittsburgh 25, Pa.

Amplifier; Counting-Rate Meter

Model 108 amplifier has a preamplifier with gain of 1, 3 or 10, which enables system gains of 21,000 to 70,000. Rise time of output pulse is 0.20 μsec; output-pulse width is 1 μsec; and range is 0–100 v, positive and negative, in 1,000 ohms.

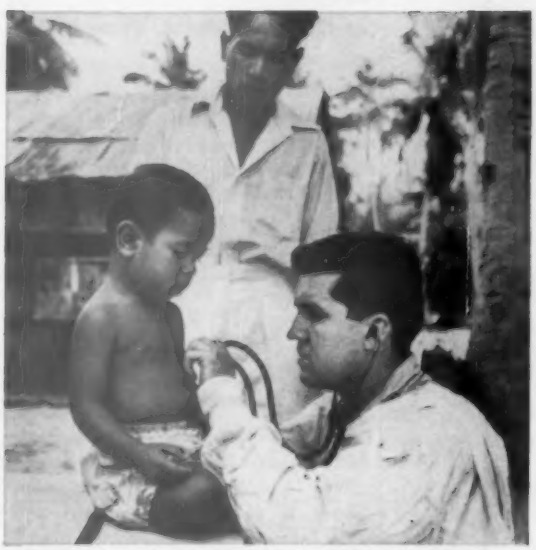
Model 502 transistorized counting-rate

OFFICIAL UNITED STATES NAVY PHOTOGRAPH

This great seaborne health center will carry a new kind of aid abroad—*with your help*. Part of the people-to-people project Hope, it will enlist 200 specialists in sharing our health skills.

Ambassador with a blackboard, the Hope specialist will help the often woefully few local medical technicians train helpers. The result: many more hands. And that means one Hope dollar is multiplied many times over.

YOUR HELP CAN COME BACK A HUNDRED TIMES OVER



One local doctor for 100,000 people. These are the odds Hope may face. Yet Hope can mean so much. The health of this child. The health of five Indonesians. *Trained* hands and only a dollar's worth of penicillin can cure them of crippling yaws.

If enough of us help, the S.S. Hope will be outbound in 1960. First port of call: Indonesia. A bold health project called Hope will be underway.

The need is crucial. Many places, too many health hazards exist. Too many people robbed of the will to live. Too few hands to help. Often, a doctor for 100,000.

Hope's approach is *practical*. Help where a nation's doctors ask help. Help them help themselves to health. By training, upgrade skills—multiply hands. Hope's doctors, dentists, nurses, and technicians will man a center complete to 300-bed mobile unit and portable TV.

You can not only make every dollar do the work of many, you can earn a priceless dividend. With health comes self-respect. People at peace with themselves are less likely to war with others.

Hope is *yours* to give. It's a people-to-people project. For one year's worth, 3½ million Americans must give a dollar. Don't wait to be asked. Mail a dollar or more now to HOPE, Box 9808, Washington 15, D.C.

ADVERTISING COUNCIL PUBLIC SERVICE

HELP LAUNCH HOPE

Here's how you can

MERCHANDISE YOUR ADVERTISING

with these handy 9" x 12" folders

Keep your sales, management and distribution people informed on your advertising. Circulate preprints, reprints, schedules and other material in these folders, and make your advertising dollars work *over* and *over* for you.

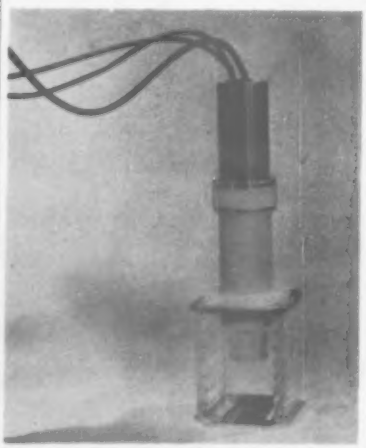
Write for illustrated folder and price list

Company Promotion Dept. Room 2710
McGraw-Hill Publishing Co., Inc.
330 West 42nd Street,
New York 36, N. Y.

meter has 8 scale ranges, extending to 600,000 cpm, displayed on 3-in. meter scale. Output is provided for 0–1-ma or 0–10-mv recorder.—Interstate Electronics Corp., 707 E. Vermont Ave., Anaheim, Calif.

Air and Hydraulic Cylinders

Low-pressure air and hydraulic cylinders are available with 1½-in.- to 8-in.-bore cylinders. Capacities are 250 psi air and 400–1,000 psi hydraulic. Cylinders are offered with a variety of mountings, rod diameters, rod ends, stroke lengths and packings.—Hanna Engineering Works, 1765 Elston Ave., Chicago 22, Ill.



Scintillation Detector Preamp

Scintillation detector preamplifier (above) features focusing control to adjust screen voltage for optimising resolution and high-voltage filtering in dynode voltage divider. Instrument can be combined with detector assembly for pulse-height analysis or integral counting. Input power requirements are 175 ma at 6.3 v a-c, 5–7 ma at 150–250 v d-c.—Nuclear-Ohio, Inc., 27105 Knickerbocker Rd., Bay Village, Ohio.

Remotely Controlled TV Unit

Remotely controlled TV camera is mounted on a tilt and pan unit that moves horizontally and vertically. Movement of camera, iris opening and zoom lens are controlled remotely and enable operator to see about anything in separation cells of Hanford's Chemical Processing Department. Tilt and pan lens allows horizontal and vertical

PARAPLEGICS MANUFACTURING COMPANY, INC.
is now producing

- **HIGH PRECISION**
  Assembly • Machining • Soldering
- **MINIATURIZED**
  Assemblies • Cables • Components
- **PRINTED CIRCUITS**
  Assembled • Soldered • Tested
- **STAINLESS STEEL**
  Fabrication • Soldering • Welding

for customers that include:
Argonne National Laboratories, Bendix Aviation, Barnes & Reinicke, Bell & Howell, Midwestern Universities Research Assn., Oak Ridge National Laboratories, Univ. of California, Wheaton Engineering Corp., and others.

Write for New Facilities Manual

PARAPLEGICS
Mfg. Company, Inc.
10070 Franklin Ave.
Franklin Park, Ill.

CONTRACT MANUFACTURERS

Gadolinium, Gadolinium chlori
Galactonic acid lactone, Gala
loride, G ntaacetat
ethanolam allic aci
Gallium c lium nit
Gallocyanin, Gallophenine, Ga
hydrol Gel
acid, G de, Ge
ethano isic a
acetate, Germyl bromide, Ger
Germanium metal, Germanium mo
te tra
te ap
Gitoxigenin, Gitoxin, Gliadin
Glucoascorbi d, Glucochlo
acid d, Gluc acid, Glucon
Glucosaminic , Glucose al
Glucose-o-carboxyanilide, Glu
Glucose dibenzylmercaptal, Gl
mercap ylme
ethylxa oxamin
pentaacetate, Glucose sodium
Glucose thioureide, Glucose u
Glucosides, Glucosido-2-pyrid
trimethylammonium Gl
curonidase, Glucu e,
tamic acid, Glut ut
dioxime, Glutara ri
anhydride, Gluta hyd
reduc ize
cam cero
de olin
c sam

OVER 20,000 CHEMICALS IN STOCK!

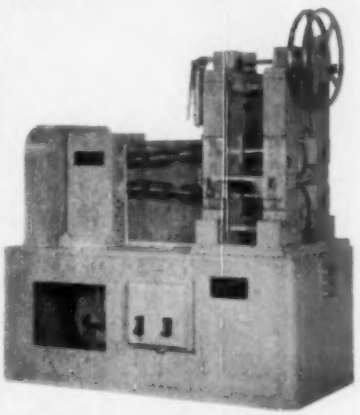
Write for Our New 138-Page Catalog!

DELTA CHEMICAL WORKS, Inc.
23 West 60th St. New York 23, N. Y.
Telephone: Plaza 7-6317

scanning with lens only. Polaroid pictures can be taken of TV screen.—General Electric Co., Hanford Atomic Products Operation, Richland, Wash.

Plastic Scintillation Fluors

Plastic scintillation fluors up to 16-in. dia and 24 in. long and weighing ~400 lb before machining (above) have been produced. Standard sizes are shipped from stock; larger sizes are produced on order.—Semi-Element, Inc., Single Crystal Div., Saxonburg, Pa.



Combination Rolling Mill

Heavy-duty, high-precision 2-high/4-high combination rolling mill (above) can operate in 6-in. × 8-in. 2-high setup or 1½-in. and 6-in. × 8-in. setup. The 2-high arrangement is used for hot or cold breakdown rolling of plate and sheet, and grooved rolls are available to process rounds, squares and other shapes. The 4-high setup cold-finish rolls strip to as thin as 0.001 in.—Loma Machine Manufactur-

E.M.I.
PHOTOMULTIPLIERS
FOR
Scintillation Counters

E.M.I. Portable Contamination Monitor Type 1

For efficiency, sensitivity and convenience, the scintillation counter, using a photomultiplier in one of its many current E.M.I. forms, is undoubtedly the most universally useful device for the detection and measurement of alpha, beta and/or gamma rays.

The range of E.M.I. photomultiplier tubes is probably the largest in the world. As well as an extensive list of standard types effectively covering all the principal photoelectronic applications, special tubes can be produced to suit specific problems. Send us your inquiries—our design team will gladly co-operate with you.

EMI

E.M.I. ELECTRONICS LIMITED
VALVE DIVISION
HAYES · MIDDLESEX · ENGLAND EE.84

Question, by R. S. Landauer, Jr. & Co., is a free periodical offered to supervisory personnel in the radiation field for distribution to their non-technical employees. It is a useful learning tool for your employees and will be helpful in meeting training requirements.

This new R. S. Landauer, Jr. & Co. employee training aid is a free service to users of Landauer Film Badge Services. Other interested parties may obtain sample copies on request. Your inquiry is welcomed. Write to the office nearest you.

R. S. Landauer, Jr. & Co.
3920 216th Street, Matteson, Illinois

Western Laboratory:
10125 W. Washington Blvd., Culver City, Calif.

CURRENT INDICATOR AND INTEGRATOR
MODEL A309A

TWO Instruments in ONE!

1. Measures currents from 1 milliampere to 3 milli-microamperes.
2. Integrates input current and registers accumulated charge.

- Wide current range: 1 x 10^{-3} to 3 x 10^{-9} amp. in 12 switch settings.
- High accuracy: 1% of full scale.
- Internal calibrating current source to check proper operation.
- Front panel switch allows instrument to be used with current of either polarity.
- Pre-setting feature provides means of safeguarding against overexposure.
- Developed especially for use with Van de Graaff and other h.v. accelerators.
- Permits many experiments with particle accelerators that would otherwise be extremely difficult if not impossible.
- Register readout gives digital accuracy on charge measurement.

For complete tech. data, write to:

Elcor inc.
1225 W. BROAD ST., FALLS CHURCH, VA.
ELECTRONIC RESEARCH • DEVELOPMENT • MANUFACTURING

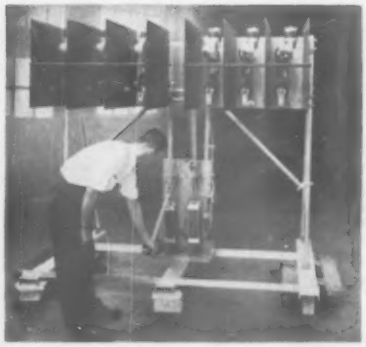
PRODUCTS & MATERIALS

Department starts on page 124

ing Co., Inc., 114 E. 32nd St., New York 16, N. Y.

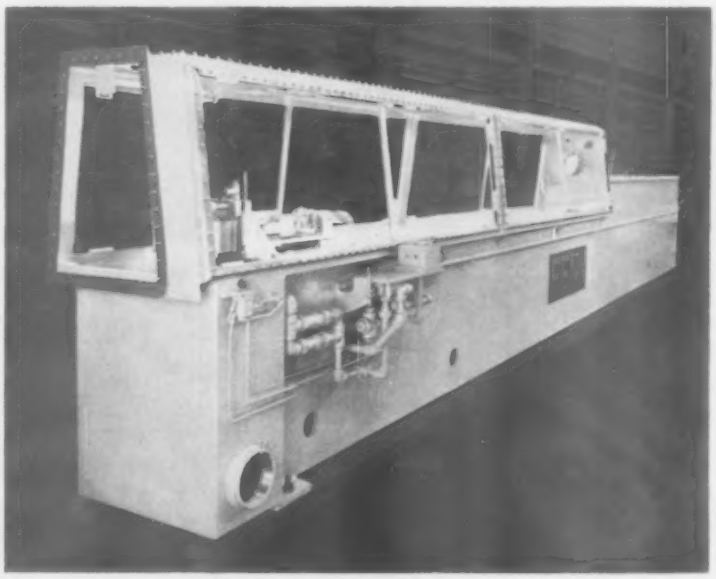
Reactor Monitor System

Scram monitor and transient recorder are separate magnetic-tape systems used in conjunction with each other to monitor a reactor. Scram monitor system has both a tape-loop recording system, which has enough tape capacity for recording on a 10-sec loop, and a tape-reel recording system. Tape loop is continuously erased and re-recorded during each 10-sec cycle as long as input-data signals are not interrupted by a scram signal. At scram, loop contents up to scram are re-recorded on reel transport as well as subsequent input-data signals. Transient recorder can record 29 data-signal inputs on reel transport. Voice and time signals are multiplexed on single channel.—Minneapolis-Honeywell Regulator Co., 10721 Hanna St., Beltsville, Md.



Switch Transfer Mechanism

Dual cylinder, double throw automatic switch transfer mechanism (above) is activated by stored energy. When a power failure occurs, mechanism opens the preferred-source-disconnect switch and closes another to instantly transfer to an emergency power source. Cylinder for preferred switch is activated by loss of preferred-source voltage.—H. K. Porter Co., Inc., Delta-Star Electric Div., 2437 Fulton St., Chicago 12, Ill.



Drawbenches for Plutonium Fuel Fabrication

A special drawbench (above) has been designed and manufactured for the fabrication of fuel for the Plutonium Recycling Test Reactor now under construction at Hanford. The benches, which will be operated at Hanford, feature a variable, pressure-compensated, flow-controlled, metering-out hydraulic system capable of exerting a 25,000-lb pull over a 12-ft stroke. Drawing speeds are 0–20 fpm. A turks head, that can be positioned remotely, is utilized for drawing other than round fuel configurations. Hydraulic lines were kept to a minimum and outside the contaminated area wherever possible; hydraulic packings can be changed remotely. The hooded bench provides personnel protection from the hazards of plutonium fabrication.—The Fenn Manufacturing Co., Fenn Rd., Newington, Conn.

Low-Priced Manipulator

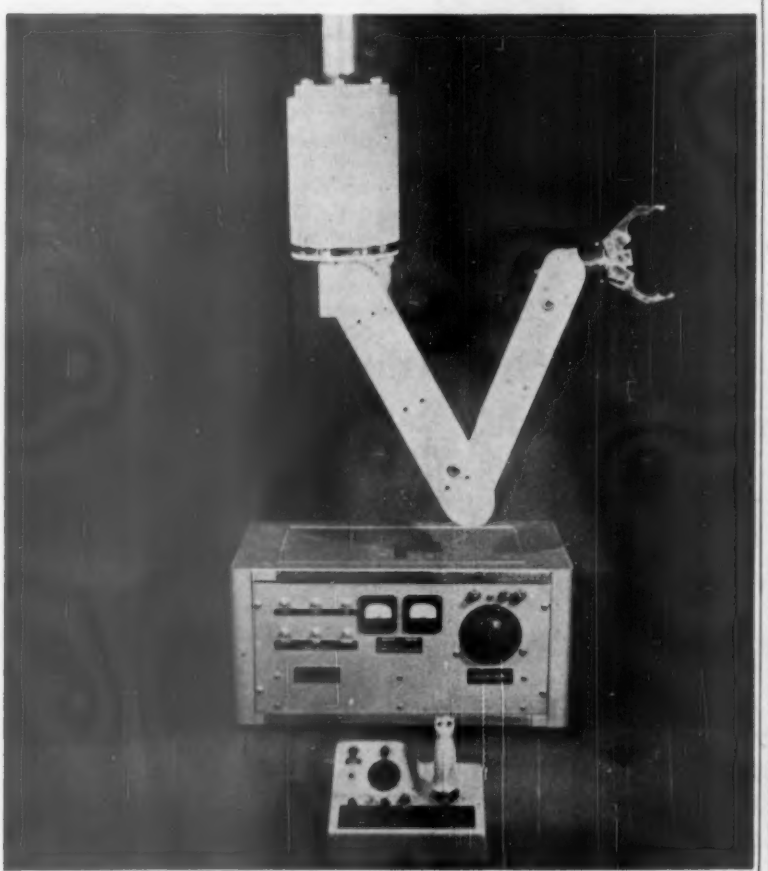
Model 100 low-priced electro-mechanical manipulator (above) permits operator to remotely handle loads up to 200 lb. Model features portable control console, high dexterity and rapid response rates.—General Mills, Inc., Mechanical Div., 1620 Central Ave., Minneapolis, Minn.

Hot Lab Absorbent Paper

Special thick absorbent paper is available for maximum protection in retaining radioactive spills. Very low ash content of paper reduces its volume significantly. Paper is available in rolls 26-in. wide from 500 to 2,000 ft long.—Eaton-Dikeman Co., Mt. Holly Springs, Pa.

Seamless Tantalum Tubing

Seamless tantalum tubing up to 60 ft long is now available. Sizes range



Remote-Handling Device

Model 122 manipulator (above) can reach all points within a 36-in.-dia sphere and has a 45-lb capacity. Transistorized power unit provides smooth and infinitely variable speed control throughout its operating range. All motors and electrical connections are in body shell above the shoulder joint. All motions with exception of shoulder joint are independent. All motions are selected by single "joystick" control. Separate knobs control speed of elbow and shoulder, pressure of grip and hand, wrist and rotational speeds.—Koelsch Electronic Development Co., Boise, Idaho.

MODEL 412 MERCURY RELAY
PRECISION SLIDING PULSER
for Precise Calibration of Single & Multi-Channel Pulse Height Analyzers

Determines Window Widths Using Principle of *Constant Angular Velocity*

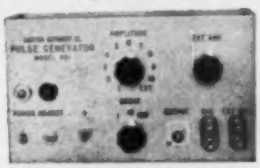
AUTOMATICALLY 10 × MORE ACCURATELY 40 × FASTER THAN CONVENTIONAL PULSERS

Incorporates Both Manual Control and Precision Motor Drive

Simulates Pulses from Scintillation Proportional, or Geiger Counters

MERCURY PULSER, Model 401
Featuring Versatility and Precision

SPECIFICALLY DESIGNED for the NUCLEAR PHYSICS LABORATORY



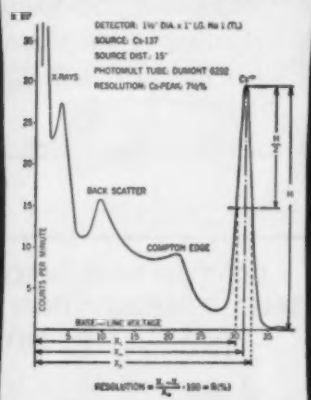
FAST RISE AND EXPONENTIAL DECAY SIMULATES SCINTILLATION, PROPORTIONAL OR GEIGER COUNTER PULSES FOR TEST AND CALIBRATION OF AMPLIFIERS, PULSE HEIGHT ANALYZERS, SCALERS, ETC.

Model 412 ..... $450.00
Model 401 ..... $125.00

Radiation Instrument Co.
P. O. Box 733 Silver Spring, Maryland

Sodium Iodide (Tl) Crystals
now available with a GUARANTEED RESOLUTION

TYPICAL GAMMA RAY SPECTRUM

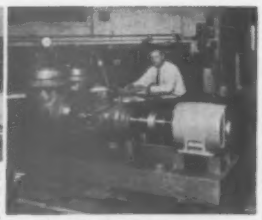


Scintex Brand Crystals are unconditionally guaranteed for one year under normal usage.

CRYSTALS DIVISION
ISOTOPES, INC.
123 Woodland Avenue, Westwood, New Jersey

This Peerless Pump is installed at the Vallecitos Atomic Plant on the first forced circulation dual cycle boiling water reactor ever built.

Peerless has had a separate research and development group working on pumps for high temperatures and pressures since 1950. Out of this group have come pumps for atomic powered submarines, reactors, steam generators.



This limited leakage pump for an Atomic Laboratory is shown above undergoing final high temperature seal tests. Parts in contact with pumpage are all of 304 stainless steel.

PEERLESS PUMP

PROVEN PUMPS FOR THE NUCLEAR AGE

Recognizing the need for special pump equipment for nuclear and related equipment, Peerless long ago set up a special development and production group. Drawing on thirty-five years of experience, this group has engineered a number of pumping elements for the extremely high pressures, low stuffing box leakage and high temperatures involved in reactor systems.

Coupled with this skill Peerless has created a group of facilities among the most modern in the pump industry. This wealth of knowledge and facilities is at your immediate disposal. Write Peerless today for assistance on your pump requirements.

Send for Facilities Brochure PR-2.

Putting Ideas to Work

fmc

FOOD MACHINERY AND CHEMICAL CORPORATION

Peerless Pump Division

SAINT GOBAIN

A company which is one of the leading nuclear concerns in Continental Europe has an important contribution to the New York Atomic Exhibition; prototype equipment for hot cells will be exhibited.

DO YOU NEED SPECIALIZED & CONCENTRATED SALES REPRESENTATION FOR NUCLEAR INSTRUMENTS, HEALTH PHYSICS, SHIELDING?

Extensive Experience, in Instrument Design, Radiological Safety Programs for State and Private Organizations and Industrial Sales Engineering, can provide Competent Sales Representation for Quality Products or Service.

Display and shipping facilities available if desired.

Write or Phone—KENNETH WADE—Ch.3-0096

Wade Products Co., 186 Fifth Avenue, New York 10, N. Y.

PRODUCTS & MATERIALS

Department starts on page 124

from 0.45 in. to 1.50 in. o.d. with wall thicknesses from 0.015 in. to 0.125 in.—Wolverine Tube Division, Calumet & Hecla, Inc., 17200 Southland Rd., Allen Park, Mich.

Remote Control for Lathe

Two-axis double-ended servo system permits remote control of small toolroom lathe (above). Longitudinal and cross-feed-position readout are performed by rack and gear drive to rotary pots. Cross-feed drive consists of d-c motor-actuator assembly coupled directly to cross-feed screw. All necessary lathe controls are provided at console.—United Hydraulics, Inc., Dayton, Ohio.

CORRECTION. Plessey Nucleonics Ltd. low-energy gamma detector has sensitivity for direct Pu radiation of 15 cps/μc, rather than 15 cps/mc as stated in February issue, p. 119.—Plessey Nucleonics Ltd., Ilford, Essex, England.

LITERATURE AVAILABLE

Silicon Zener diodes. Bulletin SR-260, 6 pp.; International Rectifier Corp., El Segundo, Calif.

Phase meters, delay lines. 4 pp.; Ad-Yu Electronics Lab., Inc., 249 Terhune Ave., Passaic, N. J.

L-Band linear accelerator. 4 pp.; Applied Radiation Corp., 2404 N. Main St., Walnut Creek, Calif.

Analog computers and accessories. 4 pp.; Computer Systems, Inc., 611 Broadway, New York 12, N. Y.

Ultrasonic thickness testers. 8 pp.; Branson Instruments, Inc., 37 Brown House Rd., Stamford, Conn.

Electromagnetic isotope separator. 6 pp.; Gamma Industrie, 52 Rue de Dunkerque, Paris 9, France.

Expanded scale meter-relays. 11 pp. Assembly Products, Inc., Chesterland, Ohio.

Precision electrical instruments. 12 pp.; Weston Instruments Div., Daystrom, Inc., 614 Frelinghuysen Ave., Newark 12, N. J.

Scintillation counting photomultipliers. 4 pp.; EMI Electronics Ltd., Valve Div., Hayes, Middlesex, England.

Thermistors and varistors. Data book, 39 pp.; Victory Engineering Corp., Springfield Rd., Union, N. J. Price $1.00.

High reliability capacitors. 16 pp.; Electron Products, Div. of Marshall Industries, 430 N. Halstead St., Pasadena, Calif.

Graphite entrainment separator. 2 pp.; National Carbon Co., Div. of Union Carbide Corp., 30 E. 42nd St., New York 17, N. Y.

Battery air sampler. 4 pp.; Gelman Instrument Co., 106 N. Main St., Chelsea, Mich.

Servomotor Catalog. 14 pp.; Helipot Div., Beckman Instruments, Inc., Fullerton, Calif.

C^{14}-labeled radiochemicals. 46 pp.; Research Specialties Co., 200 S. Garrard Blvd., Richmond, Calif.

Sealess centrifugal pumps. Bulletin 1050–4, 8 pp.;
Canned pumps for organic fluids. Technical Bulletin #6, 9 pp.; Chempump Div., Fostoria Corp., P. O. Box 35-25, Huntingdon Valley, Pa.

Niobium alloy data. 1 p.; Union Carbide Metals Co., Div. of Union Carbide Corp., 30 E. 42nd St., New York 17, N. Y.

Erbium metal, data sheet. 1 p.; Research Chemicals Div., Nuclear Corp. of America, 170 W. Providencia St., Burbank, Calif.

Platinum resistance bulb. Data file. Engelhard Industries, Inc., Instruments and Systems Div., 850 Passaic Ave., East Newark, N. J.

Differential transformer. Type 060XS-KT, 2 pp.; Schaevitz Engineering, P. O. Box 505, Camden 1, N. J.

Gasoline driven electric plants. 4 pp.; D. W. Onan & Sons Inc., Minneapolis 14, Minn.

Hand, shoe and laundry monitors. Bulletin 167, 4 pp.; Technical Associates, 140 W. Providencia Ave., Burbank, Calif.

Hand and clothing monitor. 4 pp.; EMI Electronics Ltd., Instrument Div., Hayes, Middlesex, England.

Gamma spectrometer system. 4 pp.; Nuclear Measurements Corp., 2460 N. Arlington Ave., Indianapolis 18, Ind.

Voltage regulated power supplies. 4 pp.; Kepco Inc., 131–38 Sanford Ave., Flushing 55, N. Y.

Transistorized count ratemeter. 1 p.; Interstate Electronics Corp., 707 E. Vermont Ave., Anaheim, Calif.

Instrumentation for nuclear education. 6 pp.; Baird-Atomic, Inc., 33 University Rd., Cambridge 38, Mass.

Instruments for radiation measurements. 12 pp.; Landsverk Electrometer Co., 641 Sonora Ave., Glendale 1, Calif.

Scaler-ratemeter, comparison listing. 4 pp.; Nucleonic Corp. of America, 196 Degraw St., Brooklyn 31, N. Y.

Halogen-sensitive leak detectors. GET-2935, 4 pp.; General Electric Co., Instrument Dept., Lynn, Mass.

High vacuum equipment. Catalog No. 1-60, 24 pp.; Vacuum Instrument Corp., Stepar Pl., Huntington Station, N. Y.

Emission spectrophotometer. 4 pp.; Land-Air, Inc., Instrument & Electronic Div., 2133 Adams Ave., San Leandro, Calif.

Indicating pyrometer controller. Bulletin 0035, 4 pp.; Atlantic Pryometers, Inc., 190 Warburton Ave., Hawthorne, N. J.

Instrumentation & control manufacturer. Facilities brochure, 8 pp.; Consolidated Controls Corp., Bethel, Conn.

Capabilities brochure. 8 pp.; Barry Controls, Inc., 700 Pleasant St., Watertown 72, Mass.

now more than ever

radiation monitoring you can bank on

new peace of mind comes to the wearer of this badge. Not only does he always know the full *score* on his personal exposure, but he can confidently rest on its *accuracy*, too. Continuous technical improvement in Gardray film processing and densitometry (direct electronic IBM recording now eliminates all possibility of human error) gives him this positive protection . . .

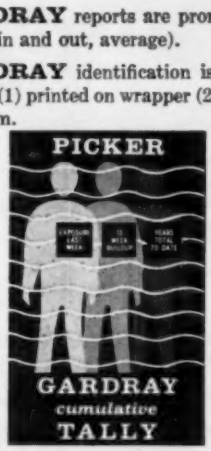
GARDRAY records exposures as low as 1 mr, as high as 300,000 mr.

GARDRAY is sensitive to gamma and x-radiations and beta radiation: reports them separately.

GARDRAY reports are cumulative tallies: (1) current week (2) 13-week total (3) year's total to date.

GARDRAY reports are prompt (two days in and out, average).

GARDRAY identification is doubly-sure: (1) printed on wrapper (2) x-rayed on film.



You can start enjoying this protection (and acquiring this peace of mind) any time. Right now, if you wish, by calling any Picker X-Ray local office. *Or write to*

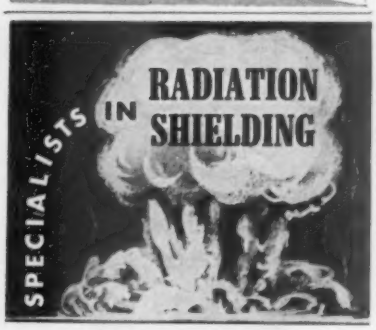
PICKER
X-RAY CORPORATION
25 So. Broadway, White Plains, N.Y.

NEW Scintillation Detectors

- NE810 Alpha Particle Detector, Consisting of .0005" sheet of plastic phosphor NE102 on a clear plastic base. This detector provides fast decay time, low gamma sensitivity and modest resolution.
- NE812 Hollow Plastic Scintillator for Beta Ray Spectroscopy and for multiple tracer studies of Beta emitters.
- NE813 Gamma Flow Detector for continuous monitoring of gamma effluents in aqueous or organic solutions.
- NE219 Liquid Scintillator for Beta counting of filter paper chromatograms and direct counting on filter paper.

Other products include Plastic Phosphor NE102 fast and slow neutron detectors, and loaded liquid scintillators.

NUCLEAR ENTERPRISES LTD.
1750 Pembina Highway
WINNIPEG 9, CANADA
Associate Co.: Nuclear Enterprises (G.B.) Ltd.
Sighthill, Edinburgh 11, Scotland



SHEET LEAD
LEAD BRICKS
LEAD PIPE and

- Lead Fittings
- Powder
- Wool

LEAD SPECIFICATIONS
SIZES and WEIGHTS

PHYSICAL • CHEMICAL PROPERTIES

SOUTHERN LEAD ROLLING COMPANY
2823 N. Westmoreland DALLAS, TEXAS
P. O. Box 6195 Phone FE 1-3241

Call or Write us for figures on your specific requirements in the NUCLEAR FIELD. We can serve you nationally or internationally.

INDUSTRY NOTES

● Tobe Deutschmann has returned to the site of his original operation, Canton, Mass., to found **Tobe Deutschmann Laboratories.** Deutschmann established the labs a few months after the dissolution of Tobe Deutschmann Corp. by the majority stockholder, Cornell-Dubilier Electric Corp. (NU, Nov. '59, 31). Deutschmann said the labs would engage in research and equipment-design for the entire field of plasmas and magnetohydrodynamics, including design of new capacitors for the fusion program.

● **Tracerlab Film Badge Service** has overcome customs problems across the Canadian border and is now offering its film-badge service to Canadian customers through Waltham, Mass., headquarters.

● **Oregon Metallurgical Corp.,** whose high-purity reactive metals plant had been shut down by fire, has returned to production; the firm supplies vanadium and other metals to the atomic-energy program.

● AEC, as of Feb. 1, reported the signing of 11 "stretch-out" contracts with **uranium-concentrate suppliers;** another 14, most expiring by March 31, 1962, had yet to be extended to the Dec. 31, 1966, extension date. AEC's stockpile of U concentrates has been building up and the stretchout of deliveries to 1966 has been aimed at keeping the buildup to a minimum.

● Consolidated Diesel Electric Corp., supplier of nuclear controls and many other industrial commodities, has changed its name to the **Condec Group.,** Stamford, Conn.

● The price for **low-boron magnesium oxide**—a high-refractory, low-neutron-absorbing material in wide demand for nuclear facilities—has been reduced by about 50% by International Minerals & Chemical Corp. New prices are $155/ton in bulk and $160/ton in bagged carloads of 30 tons minimum; former prices were $235 and $240/ton, respectively.

EXPANSIONS. A wholly-owned subsidiary of Burns and Roe, the **Burns and Roe Western Hemisphere Corp.,** has been established to handle engineering and construction projects everywhere in the hemisphere except in the U. S. . . . **Astra, Inc.,** Raleigh, N. C., has formed a Medical Engineering div. to handle problems of measurement, analysis and design in medical research. . . . **Aerojet-General Corp.** has acquired a minority interest in **Electro-Optical Systems, Inc.,** Pasadena, Calif., developer of ion and plasma propulsion systems and other advanced power systems. . . . **Beckman Instruments** has established a Special Products div. to develop new products in areas not presently covered by the firm's six divisions. . . . **Panellit, Inc.,** Skokie, Ill., has been converted into an operating unit of **Information Systems, Inc.,** Los Angeles, which, in turn, has been taken over by **Chance Vought Aircraft,** Dallas (80% interest). . . . **Victoreen Instrument** has acquired **John E. Fast & Co.,** Chicago electronics firm; the new subsidiary will boost Victoreen's sales by $5-million annually, Victoreen said. . . . **R. S. Landauer, Jr., and Co.** has purchased the Dosifilm (film badge) operation of the **American Nuclear div., American Electronics;** the purchase extends Landauer's film-badge operations to the West Coast, since Dosifilm operates out of Culver City, Calif.

FINANCIAL. Record sales and earnings of $7-million and $626,062, respectively, were reported by **High Voltage Engineering** for the year ended Dec. 31; they were up 23 and 44%, respectively, from 1958. With earnings of two subsidiaries, HVEC's total earnings were $733,062 or $1.87/share. Dec. 31 backlog was $9.2-million, up 42% from a year earlier. . . . **Beckman Instruments** reported a 20% increase in sales and a 50% increase in earnings for the six months ended Dec. 31; sales were $25,442,965, with earnings of $1-million (93 cents/share). . . . **Cenco Instruments** has predicted earnings of at least $1.15/share on sales of more than $21-million for the year ending April 30, fiscal 1960; the same '59 figures were 72 cents and $15-million. . . . **National Research Corp.** reported a profit of $17,356 on sales of $6,888,076 for the year ended Dec. 31; NRC had a loss of $500,000 in 1958 on sales of $5.5-million. . . . **Nuclear-Chicago** reports that February was the best month in its history for both shipments and orders; the quarter ended Feb. 29 was also expected to be a record one as N-C adjusted to its move to new quarters.

NUCLEAR CAMPUS

● **First research grant** under the Exchange and Training Program of the International Atomic Energy Agency has been awarded to R. P. Agarwala, India, for a year of research in solid-state physics and chemistry at Massachusetts Institute of Technology. The grants will go to scientists working on a promising line of research but hampered by a lack of adequate facilities.

● Ardath H. Emmons of the Univ. of Michigan's Phoenix Project has joined the **Univ. of Missouri** to direct design and installation of a research reactor and associated lab facilities. The state government has appropriated $1,250,000 for the center and additional federal and private funds will be sought. Construction will be scheduled in about a year. When the facility is ready after another year, Emmons will direct all research and instructional uses of it.

● Instructors from the **Univ. of Nebraska** and **Atomics International** have been taking the 12-man supervisory staff for the Hallam, Neb., sodium power reactor through a 23-week training course. The group has completed a 9-week course in atomic and nuclear physics in Nebraska and is undergoing 14 weeks of further training (including 8 weeks on the Sodium Reactor Experiment) in California. Operational target date for the Hallam reactor is April 1961.

COURSES. A lab and lecture course in **nuclear measurements** will be offered as of the 1960–61 academic year at Princeton Univ.; the course is part of a buildup in nuclear engineering training at Princeton with the aid of a $40,000 AEC grant for purchase of a small accelerator, a subcritical reactor and other radiation equipment.

Oak Ridge Institute of Nuclear Studies is offering its four-course, six-week curriculum on **techniques of using radioisotopes** (NU, Oct. '59, 129) on the following dates: May 2–June 10; July 25–Sept. 2; and Sept. 6–Oct. 14.

The Gordon Research Conference this year in New Hampshire is offering **nuclear chemistry,** June 27–July 1, at Colby Junior College; **chemistry and physics of isotopes,** July 4–8, New Hampton School; and **radiation chemistry,** July 18–22, New Hampton School.

LAND-AIR, INC.
NOW OFFERS COMPLETE
COMPUTER SERVICE

ANALOG COMPUTING EQUIPMENT

for problems having complex equations where several dependent variables are involved. This method offers speed and flexibility as it performs all of its operations simultaneously, rather than in sequence.

DIGITAL COMPUTING EQUIPMENT

with unusual flexibility of programming schemes. Ideally suited to both repetitive and non-repetitive problems, regardless of complexity.

Take advantage of this experienced, versatile engineering staff to solve your engineering, research, manufacturing or production problems

Computer Center service is offered in three ways for your convenience: 1) Computer Center personnel to perform the entire analysis, programming, and solution of a given problem; 2) the client, when qualified, performs the analyses and programming, and operates the computer with staff personnel assisting as necessary; 3) center and client personnel form a team to work together in computer programming, operation and analysis of the results of the problem.

Land-Air, Inc. has computer programming and operation experience dating back to 1949, at which time the monitoring and measuring of missile performance at Pt. Mugu, California was contracted to Land-Air. Since that time, our staff engineers have participated in the solution of a wide variety of problems in many different types of industry. This experience is available to clients who do not have computing equipment available, who wish to gain experience with computing equipment, or who require additional personnel or computer time to supplement their own facilities. In all cases, it is the objective of the Land-Air Computing Center to apply creative efforts to obtain the best solution to problems, with positive results obtained with a minimum of computing and programming time.

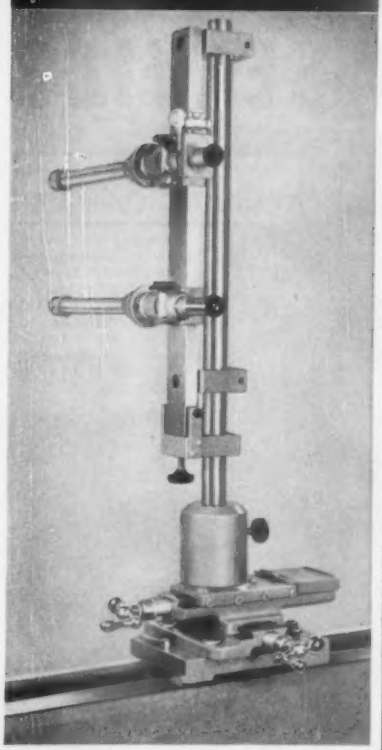
- AC and DC Rotating Machine Simulation
- Aircraft and Missile Simulation
- Automotive Engine and Suspension Problems
- Chemical Reactor Simulation
- Control System Dynamics
- Electrical System Analysis
- Flutter and Vibration Studies
- Guidance System Design
- Heat Transfer
- Implicit Synthesis
- Linear and Non-Linear Programming
- Nuclear Reactor Simulation
- Process Control
- Structural Analysis

Land-Air INC.
a subsidiary of California Eastern Aviation, Inc.

For further information and literature, phone UNderhill 7-7550 or write to:

7444 WEST WILSON AVENUE
CHICAGO 31, ILLINOIS

INSTRUMENTS TO MEASURE LINEAR DIMENSIONAL CHANGES



Instrument shown measures specimens 2" to 12" long. Total range 0.040", reading to 0.00001". Has relay lenses for 8" working distance. Adjustment in 3 axes. Mounted on lathe bed type ways for use with multiple specimen setups. This instrument is representative of a line especially suited to measurements at high temperatures.

For help with your precision measuring problems, call on Gaertner experience

Your measuring problems may very well be nicely solved with optical instrumentation. Gaertner Scientific Corporation can probably recommend a standard or modified instrument to meet your particular needs. If necessary, we are fully equipped to design and build special instrumentation.

Gaertner has designed and built precision, scientific, optical and measuring instruments for over 60 years. Write or phone, and put this experience to work for you.

1257 Wrightwood Ave., Chicago 14, Ill. • BU 1-5335

Gaertner SCIENTIFIC CORPORATION

NEWSMAKERS

Ralph F. Lumb has left his vice-presidency at Quantum, Inc., to assume direction of the Western New York Nuclear Research Center, Univ. of Buffalo. Lumb had been technical consultant to the project for two years.

Food-irradiation expert **Herman Kraybill** has joined the U. S. Public Health Service to help in the Service's new program for collating and publishing data on radiation in the environment. Kraybill had been a consultant on food irradiation at Curtiss-Wright (NU, Jan. '60, 112); before that he was project leader on the animal and human-feeding program with irradiated food at the Army's Medical Research and Nutrition lab, Fitzsimmons Hospital, Denver.

Kraybill

Two former employees of the Baird-Atomic group have joined Atomium Corp. **Robert Hindel,** former chief engineer in B-A's Atomic div., has been named chief engineer at Atomium; **Wm. K. Goolishian,** who had spent several years with Atomic Instrument Co. before it was merged with Baird, has been named chief accountant.

Ernest C. Rumbaugh has been appointed manager of the Submarine Advanced Reactor Project (SAR) at Knolls Atomic Power Laboratory. Rumbaugh had been manager of reactor engineering on SAR. He succeeds **John D. Selby,** who has been assigned to handle initial development of Knolls' latest submarine reactor project—the Natural Circulation Reactor.

Rumbaugh

Russell D. O'Neal, former general manager of the Bendix Systems div., has been elected vice-president in charge of engineering for the corporation, Bendix Aviation. O'Neal is a member of the American Nuclear Society, Atomic Industrial Forum and Institute of Radio Engineers. **Roy J. Sandstrom** succeeds him and **L. B. Young** was named assistant to Sandstrom.

A key man in the monumental effort that went into AEC's 10-year program for civilian power reactors, **Harold Vann,** has joined Jackson & Moreland.

A. Charlesby, British authority on radiation effects and radiation physics, particularly in the plastics area, has agreed to serve Radiation Applications, Inc., as senior scientific advisor. Charlesby is a professor of physics at the Royal Military College of Science and a consultant to the U. K. Atomic Energy Authority. New staffers at Radiation Applications: **Herbert M. Schoen,** formerly of American Cynamid, project director on foam-systems development; **Kenneth D. Ziegel** of Esso Research and Engineering, supervisor of Raibond (graft copolymerized teflon) production and studies on improved radiation-source utilization; **Paul A. Scardaville** of Intercontinental Corp., research chemist on ion-exchange membranes; **Algird J. Karalis,** part-time consultant.

Adolph I. Snow has been appointed director of a recently created Radiation div. at Sinclair Research Laboratories. Snow had directed Sinclair's program on radioactive tracers and effects of radiation on petroleum.

A former health and safety officer at AEC's Lockland Operations Office, **Richard A. Rossi,** has joined Cross-Malaker Labs as senior engineer.

Donald A. Dunn, recently of Stanford Univ., has been named director of the new Research div. of electron-power-tube manufacturer Eitel-McCullough. The new division will consolidate and expand scattered Eimac research programs.

Interstate Electronics Corp., Anaheim, Calif., has shifted the director of its Nuclear Instrumentation dept., **Hugh M. Griffin,** to sales manager for all Interstate products.

Merril Eisenbud, formerly chief of AEC's New York Operations Office and now of New York Univ., has been elected president of the New York Section of the Health Physics Society. **Lillian Jacobson** of Presbyterian Hospital, Newark, N. J., was elected vice-president; and **Lee Gemmell** of Brook-

haven National Laboratory was re-elected secretary-treasurer.

A public information specialist long associated with nuclear energy has been named executive secretary of the 16-state Regional Advisory Council on Nuclear Energy. He is **Robert H. Solomons III,** former director of Kentucky's Division of Nuclear Information, who took his new post March 1 at RACNE headquarters, Atlanta.

Solomons

F. R. Bruce, associate director of the Chemical Technology div. at Oak Ridge National Laboratory, has been appointed to a new post: director of radiation safety and control. The post was created after the most recent of a series of accidents at ORNL—a chemical explosion involving plutonium during November (NU, March '60, 31).

E. B. Gunyou, who left Alco Products in early 1959 to join Curtiss-Wright, has rejoined Alco as director of all nuclear technology activity in the company's nuclear power engineering dept. Alco has also brought in **W. K. Stromquist** as chief of plant-system engineering, same department. Stromquist had been supervisor of the Reactor Systems section, Atomic Power dept., Westinghouse. Active in the atomic energy field since he joined Oak Ridge in 1946 as a chemical engineer, Stromquist has also worked for AEC and du Pont at Savannah River. Gunyou is program chairman for the Nuclear Congress Apr. 3–8 at New York City's Coliseum.

Gunyou

Stromquist

Correction: **Lawrence F. Boland** has been elected executive vice-president of Beryllium Corp., rather than Brush Beryllium (NU, March '60, 163).

DR. EDWARD HEROLD DR. LOUIS MALTER DR. ROBERT JEPSEN

TOP LEADERSHIP IN HIGH VACUUM

Varian recently announced the creation of a separate Vacuum Products Division as a direct result of the universal acceptance received by Varian's VacIon® Pumps since their introduction two years ago.

The Varian men pictured above provide the managerial and research leadership which assures continued progress in high vacuum and other electronic fields.

The VacIon Pump, a unique electronic device for achieving clean, ultra-high vacuum, was originally developed at Varian Associates to improve the quality of the company's microwave tubes. The exceptional simplicity and reliability of VacIon Pumps have since led to widespread acceptance for research and production in all applications requiring high vacuum. For an insight into the applications and importance of this new equipment, please write for a comprehensive brochure and technical data. Address Vacuum Products Division.

40 LITER PER SECOND VACION PUMP V-11404

VARIAN associates

PALO ALTO 41 CALIFORNIA

Representatives thruout the world

KLYSTRONS, WAVE TUBES, GAS SWITCHING TUBES, MAGNETRONS, HIGH VACUUM EQUIPMENT, LINEAR ACCELERATORS, MICROWAVE SYSTEM COMPONENTS, NMR & EPR SPECTROMETERS, MAGNETS, MAGNETOMETERS, STALOS, POWER AMPLIFIERS, GRAPHIC RECORDERS, RESEARCH AND DEVELOPMENT SERVICES

Rare Earths

are doing these jobs in ceramics now

Producing intense and unusually "clean" colors such as yellow, blue and pink for porcelain enamel glazes.

Producing microwave ferrite components for use in isolators, circulators, switches, and phase shifters based on Faraday rotation in circular waveguides.

Producing high neutron opacity cermets and ceramics with desirable daughter reaction products for nuclear control rods.

Producing excellent dielectric ceramic components for high and low temperature applications, and flame-spray coatings for metal components.

Your current program can now include a screening of the many interesting potentials for rare earth oxides because these oxides are readily available in quantity. We shall be pleased to assist you with your application.

Copyright 1960, Michigan Chemical Corporation RE-60-1

RARE EARTHS AND THORIUM DIVISION
MICHIGAN CHEMICAL CORPORATION
682 North Bankson Street, Saint Louis, Michigan

PRASEODYMIUM • NEODYMIUM • SAMARIUM • EUROPIUM • GADOLINIUM • TERBIUM • DYSPROSIUM • HOLMIUM • ERBIUM • THULIUM • YTTERBIUM • LUTETIUM • YTTRIUM

NUCLEAR CALENDAR

Apr. 6–8—Annual Meeting of Institute of Environmental Sciences, Los Angeles (*Biltmore*). Contact Jerry Bakalish, 6102 Warwood Rd., Lakewood, Calif.

Apr. 18–19—Symposium on Radioactivity in Man, Measurements and Effects of Internal Gamma Ray Emitting Radioisotopes, Nashville, Tenn. (*Vanderbilt Univ.*). Contact George R. Meneely, School of Medicine, Vanderbilt Univ., Nashville 5.

Apr. 25–29—Seminar on Codes for Reactor Computations, sponsored by International Atomic Energy Agency, Vienna. **May 10–13**—IAEA Symposium on Fuel Element Fabrication (special emphasis on cladding materials), Vienna. **June 7–13**—IAEA Symposium on Radiation Dosimetry, Vienna. **Aug. 8–13**—IAEA Symposium on Ionizing Radiation Effects on Seeds and Improvement of Crops, Karlsruhe, Germany. **Sept. 6–17**, IAEA Conference on Radioisotopes in Physical Sciences and Industry, Copenhagen. Contact IAEA, 11–13 Kartner Ring, Vienna 1, Austria.

May 2–3—2nd Conference on Reactions between Complex Nuclei, sponsored by American Physical Society, Gatlinburg, Tenn. Contact R. S. Livingston, Oak Ridge National Laboratory, Oak Ridge, Tenn.

May 9–11—3rd National Power Instrumentation Symposium, sponsored by Instrument Society of America, San Francisco. Contact ISA, 313 Sixth Ave., Pittsburgh 22, Pa.

May 9–13—Instrument Society of America, San Francisco. For papers on measurement and control instruments contact Martin E. Kantor, c/o General Atomic, P. O. Box 608, San Diego 12, Calif.

May 12—Advanced Propulsion Reactor concepts, unclassified session at American Rocket Society semiannual meeting, at Los Angeles (*Ambassador*). Contact C. J. Wang, c/o Space Technology Labs, Box 95001, Los Angeles 45.

May 24–26—1960 Convention of American Society for Quality Control, San Francisco. Contact ASQC, 161 W Wisconsin Ave., Milwaukee, Wis.

June 5–9—World Power Conference on Solving Power Shortage Problems (Sectional Meeting), sponsored by International Executive Council of World Power Conference, Madrid, Spain. Contact D. José Pérez Pozualo, Spanish Natl. Committee, General Pardinas, 55, Madrid.

June 12–15—Annual Meeting of American Nuclear Society, Chicago (*Palmer House*). Contact Octave J. DuTemple, 86 E. Randolph St., Chic. 1.

June 15–29—International Congress and

Exhibition on Electronics, Nuclear Energy and Cinematography, Rome (*Palazzo dei Congressi*). Contact Evandro Benvenuti, Via della Scrofa, 14, Rome.

June 16–18—5th Annual Symposium of American Scientific Glassblowers Society, Pittsburgh, Pa. (*Penn-Sheraton*). Session on glass apparatus for radioisotopes and radiology. Contact W. E. Barr, Gulf Research & Development Co., P. O. Box 2038, Pittsburgh 30, Pa.

June 20–21—First Annual Meeting of Institute of Nuclear Materials Management, Columbus, Ohio (*Neil House*). AEC is holding its Annual Materials Management Meeting at same location June 23–25. Contact Harley L. Toy, Battelle Memorial Institute, Columbus.

June 20–26—Congress on Nuclear Energy, sponsored by Italy's Comitato Nazionale per le Ricerche Nucleari (CNRN), Rome. Contact C. M. C. Office, CNRN, Via Belisario 15, Rome.

June 23–24—2nd Youth Conference on the Atom, Univ. of Michigan, Ann Arbor. Contact Bosell & Jacobs, 2 W. 45th St., N. Y. 36, N. Y.

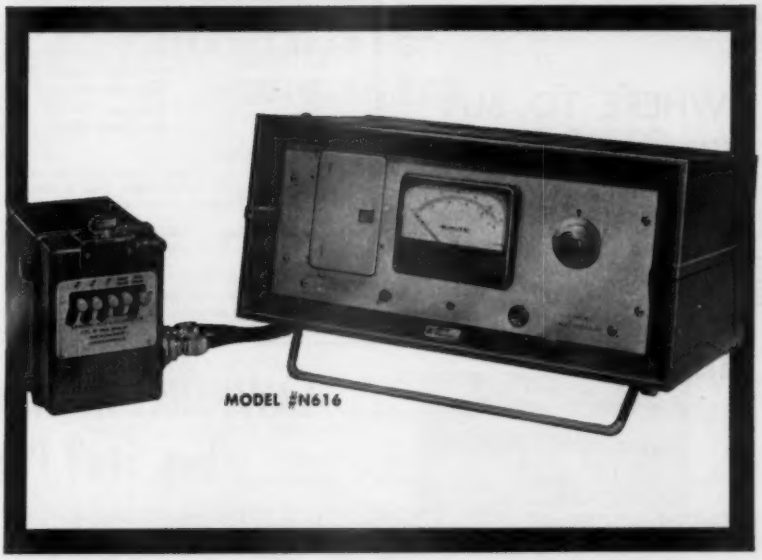
June 29–July 1—Annual meeting, Health Physics Society, Boston (*Statler-Hilton*). Contact J. W. McCaslin, 1808 Rose St., Berkeley, Calif.

July 21–27—3rd International Conference on Medical Electronics, London. Contact Secretary, Institution of Electrical Engineers, Savoy Place, London W. C. 2, England, or Lee B. Lusted, Dept. of Radiology, Univ. of Rochester School of Medicine, Rochester 20, N. Y.

Aug. 11—AEC information meeting on small reactors, Oak Ridge. Contact R. A. Charpie, ORNL, Box 4, Oak Ridge.

Sept. 13–15—Fifth International Instruments and Measurements Conference, including section on nuclear instrumentation, and an exhibition of commercial instrumentation, Stockholm. Contact H. von Koch, Royal Institute of Technology, Stockholm 70, Sweden.

Dec. 11–16—American Nuclear Society–Atomic Industrial Forum joint meeting, San Francisco (*Mark Hopkins* and *Fairmont*). 12–15th Atomfair West, first West Coast nuclear industrial exposition (*Masonic Memorial Building*). Contact W. Kelly Woods, Vallecitos Atomic Laboratory, Pleasanton, Calif., for ANS program; Edwin Wiggin, AIF, 3 E. 54 St., N. Y. 22, for Forum program; Dan Scherer, AIF, for Atomfair. 11–14—8th Hot Laboratory and Equipment Conference. Paper summaries due May 16. Contact James R. Lilienthal, Los Alamos Scientific Laboratory, P. O. Box 1663, Los Alamos, N. M.



NEW . . . . . **THE EKCO N616 VIBRATING REED ELECTROMETER**

Unsurpassed performance and flexibility at low cost. Proudly offered as successor to the widely used and well known EKCO N572 Electrometer.

The name Ekco Electronics, Ltd. signifies more than world-wide representation and acceptance on six continents. Whether it be instruments for precise radiation measurements, unique laboratory research, reactor monitoring, public health and plant safety, or industrial gaging through isotopes, Ekco Electronics, Ltd. on the nameplate of an instrument represents the acme of excellence in design, performance, dependability and long-lasting value. An impressive list of companies and institutions throughout the world use Ekco equipment.

The above instrument is one of a large and complete range of EKCO instruments described more completely in the EKCO catalogues available upon request. We cordially solicit your inquiry. Write today for name of franchised EKCO representative nearest you.

NOW FULLY PROVEN

the EKCO low-cost Scintillation System for Tritium and Carbon 14 counting.

The EKCO Scintillation Counter has been thoroughly evaluated and proved in actual use. It is accepted as the best dollar value on the market . . . convincing proof that superb instrumentation need not be expensive.

AVAILABLE FOR IMMEDIATE DELIVERY

EKCO ELECTRONICS, LTD.

In U. S. A., address all inquiries to:
American Tradair Corporation, 34-01 30th Street,
Long Island City 6, New York
ELSEWHERE: Ekco Electronics Ltd., Southend, England

WHERE TO BUY

Featuring additional products, specialties and services for Atomic Power, Nuclear Engineering and Applied Radiation.

NEW FROM TEXAS NUCLEAR CORP.

- For focusing an ion beam at large distances from the accelerator
- Cancels astigmatism produced by analyzing magnet
- Increases useful ion beam intensity

TEXAS NUCLEAR CORPORATION

P. O. Box 9267 Dept. F Austin 17, Texas

PROFESSIONAL SERVICES

ASTRA, Inc.

For Your Atomic Energy Problems

Nuclear Analyses. Reactor Specifications and Designs, Radiation Shielding Design and Analysis. Criticality Hazards Studies. Thermodynamics and Heat Transfer Analysis, Facilities Planning, Health Physics.

P. O. Box 226 Raleigh, North Carolina
VAnce 8-4386 CABLE: "ASTRA"

INTERNUCLEAR COMPANY

Nuclear consultants, engineers, and designers

Economics of Nuclear Power, Reactor Analysis and Design, Shielding, Special Applications

Clayton 5 Missouri

NUCLEAR REACTOR ASSOCIATES

Nuclear Engineering & Economic Consultants

General economic consulting—Marketing—Nuclear, metallurgical, mechanical, architectural and industrial engineering.

436 Farmington Avenue, Hartford 5, Connecticut
Telephone: ADams 6-3211

NUCLEAR CONSULTANTS

Engineering services in heat transfer, core nuclear and thermo analysis, coolant technology, shielding, kinetics, power plant analysis. Application & programming for digital and analog computers.

PC-3770 NUCLEONICS
Class. Adv. Div., P.O. Box 12, N. Y. 36, N. Y.

WHEN TIME IS SHORT . . . .

put the solution of your problems up to a specialized Consultant. His broad experience may save you months of costly experimentation.

EMPLOYMENT OPPORTUNITIES

NATIONAL COVERAGE

The Advertisements in this section include all employment opportunities —executive, management, technical, selling, office, skilled, manual, etc.

Positions Vacant | Civil Service Opportunities | Employment Agencies
Positions Wanted | Selling Opportunities Wanted | Employment Services
Part Time Work | Selling Opportunities Offered | Labor Bureaus

RATES

DISPLAYED

The advertising rate is $25.35 per inch for all advertising appearing on other than a contract basis. Contract rates quoted on request.

An advertising inch is measured ½" vertically on a column—2 columns—30 inches to a page.

Subject to Agency Commission.

UNDISPLAYED

$2.10 per line, minimum 3 lines. To figure payment count 5 average words as a line.

Position Wanted ads are ½ of above rate.

Box Numbers—counts as 1 line.

Discount of 10% if full payment is made in advance for 4 consecutive insertions.

Not subject to Agency Commission.

Send NEW ADS or Inquiries to Classified Adv. Div. of NUCLEONICS, P. O. Box 12, N. Y. 36, N. Y.

LAWRENCE RADIATION LABORATORY has Staff Positions Open

. . . For research and development in the fields of nuclear explosives and high temperature nuclear reactors.

• METALLURGIST, Ph.D. . . . to assume technical direction of applied research metallurgy group. Broad theoretical and practical background in physical metallurgy required. Experience in metallurgy of beryllium, thorium, uranium, plutonium is desirable. Current problems include:

1. Basic studies on alloy systems; TTT diagrams, phase diagrams, mechanical and physical properties, and recrystallization.
2. Deformation of metals and ceramics at high temperature; deformation of metals at high strain rate.
3. Corrosion mechanisms and coating development for corrosion protection.

• METALLURGISTS, B.S.-Ph.D. . . . Preferably with some ceramics background. Work involves mechanical property measurements at high temperatures of refractory metals, oxides, and intermetallics (creep, rupture, etc.) and development of oxidation resistant coatings. Experience in metallurgy of materials used in nuclear technology required.

• SENIOR WELDING ENGINEER, B.S.-M.S. . . . to develop methods for welding or brazing materials for nuclear applications in special forms and shapes.

U. S. CITIZENSHIP REQUIRED

Please send confidential resume
to Mr. J. D. Beckham, Personnel Department.

LAWRENCE RADIATION LABORATORY
(Livermore Site)
P. O. BOX 808 J, LIVERMORE, CALIFORNIA
(One hour from downtown San Francisco)

for **POSITIONS** in the **NUCLEAR FIELD . . .**

WRITE US FIRST!
Use Our Application
No Resume Required

Our national coverage and technical experience in the nuclear field offer the maximum opportunity to achieve your goal.

Confidential Handling
Employer Pays Fee

Write: Arthur L. Krasnow

ATOMIC PERSONNEL, INC.

1518 Walnut St. • Phila. 2, Pa. • PE 5-4908
An Employment Agency for the Nuclear Field

Manager Metallurgical Dept.
Salary $18,500

Responsible for development of all new products in refractory metals. Improve all processes. Direct research program. Total compensation for these duties will result in a financial figure of Twenty Five Thousand, within a few years. Must have the administrative background to take complete charge.

Esquire Personnel Service, Inc.
202 S. State St. Chicago 4, Illinois

DEVELOPMENT ENGINEER CONTROLS
$9,000–$11,000

Position will lead to chief engineer. Company purchased new plant in midwest. A graduate M.E. or E.E. with three or more years in D&D of individual controls will qualify. Company will assume all expenses. Reply in strict confidence.

MONARCH PERSONNEL
28 E. Jackson Blvd., Chicago 4, Illinois

Need Engineers?

Contact them through this

EMPLOYMENT OPPORTUNITIES section

▶ HEALTH PHYSICIST

or

▶ INSTRUMENT SPECIALIST

to join the staff of

NUCLEONICS

Send resume, salary requirements to

The Editor, NUCLEONICS
330 West 42nd Street
New York 36, New York

ADDRESS BOX NO. REPLIES TO: Box. No. Classified Adv. Div. of this publication. Send to office nearest you.
NEW YORK 36: P. O. BOX 12
CHICAGO 11: 520 N. Michigan Ave.
SAN FRANCISCO 4: 68 Post St.

POSITIONS VACANT

Nuclear Engineer for stimulating, maturing assignment that will lift you out of the narrow confines of your present duties. The position, at one of the focal points of the nuclear industry, demands technical competence, articulateness, personal effectiveness, and above all else a sense of excitement about the nuclear field and the age in which we live—don't apply if you don't have these qualities. Salary: competitive. Location: East Coast. Write telling us who you are, what you've done, where you want to go, and what your salary requirements are. P-3442, Nucleonics.

POSITION WANTED

B.S. in Physics. Several years selling & business management experience. Age 34. Would like to join small mfg. concern. Have some capital to invest. Reply PW-3732, Nucleonics.

Nuclear Sales Engineer for DC or NY location, preferably. Trained and experienced in all research instrumentation, radiochemicals and reactor components. PW-3878, Nucleonics.

"Put Yourself in the Other Fellow's Place"

TO EMPLOYERS
TO EMPLOYEES

Letters written offering Employment or applying for same are written with the hope of satisfying a current need. An answer, regardless of whether it is favorable or not, is usually expected.

MR. EMPLOYER, won't you remove the mystery about the status of an employee's application by acknowledging all applicants and not just the promising candidates.

MR. EMPLOYEE you, too, can help by acknowledging applications and job offers. This would encourage more companies to answer position wanted ads in this section.

We make this suggestion in a spirit of helpful cooperation between employers and employees.

This section will be the more useful to all as a result of this consideration.

Classified Advertising Division
McGRAW-HILL PUBLISHING CO., INC.
330 West 42nd St., New York 36, N. Y.

• PHYSICISTS
• ENGINEERS
• METALLURGISTS

For ATOMIC POWER PROGRAMS
on the
San Francisco Peninsula

Advanced Technology Laboratories of American-Standard requires senior nuclear scientists and engineers for key positions on challenging projects:

Physics and Kinetics of the Variable Moderator Reactor. In conjunction with a critical experiment, advanced methods are being developed for the design of this boiling water reactor.

Pressurized Water Reactor Design.
Designs are being developed for small process heat pressurized water reactors.

Application to Missiles and Rockets.
Advanced propulsion and auxiliary power sources are under study.

Advanced Fuel-Element Development.

Openings for the Following:

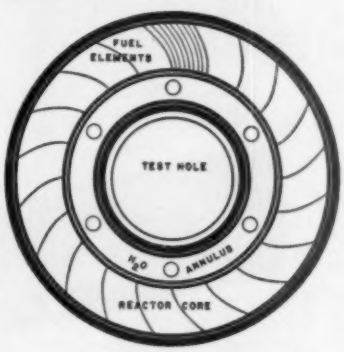
1. Senior Instrument Systems Engineers to design instrumentation systems for research and power reactors.
2. Senior Nuclear Engineers for nuclear and thermal analysis.
3. Senior Reactor Physicists for theoretical analysis of critical experiments on the VMR boiling water reactor and mercury mist cooled fast reactors.
4. Senior Metallurgical and Ceramics Engineers for research and development on advanced materials and components for nuclear applications.

Please send your resumes in confidence to:

Dean W. Townsend, Manager
Personnel Administration
Advanced Technology Laboratories
A Division of American-Standard
369 Whisman Road
Mountain View, California

ADVANCED *Technology* LABORATORIES
A DIVISION OF AMERICAN-Standard

One Example of Internuclear Work



DESIGN AND DEVELOPMENT FOR THE FLUX TRAP CONCEPT OF AN ADVANCED ENGINEERING TEST REACTOR

• ANOTHER EXAMPLE - *Continuing consulting services to SENN*

Interesting jobs are available for reactor engineers who would enjoy participation in the growth of a small and independent company with excellent salaries and employee benefits

In particular . . . **NUCLEAR ENGINEERS**
REACTOR PHYSICISTS
REACTOR DESIGN ENGINEERS
are needed

Call or write: TECHNICAL DIRECTOR

INTERNUCLEAR CO. PA 7-2668 **Clayton 5, Mo.**

KNOW-LEDGE

Biochemistry and Biophysics
DECEMBER 1959 VOL. 85, NO. 2 ARCHIVES OF BIOCHEMISTRY AND BIOPHYSICS
TRANSACTIONS OF AMERICAN SOCIETY FOR METALS Vol. 51 1959
NUCLEONICS
RADIATION RESEARCH 1960
JOURNAL OF INORGANIC & NUCLEAR CHEMISTRY
JOURNAL OF APPLIED PHYSICS
THE JOURNAL OF PHYSICAL CHEMISTRY
ANALYTICAL CHEMISTRY
THE JOURNAL OF BIOLOGICAL CHEMISTRY
Properties of Reactor Materials
SECOND UNITED NATIONS INTERNATIONAL CONFERENCE ON THE PEACEFUL USES OF ATOMIC ENERGY

. . . the only product of research and development at Argonne, is made available to the scientific community principally through publication in the professional literature.

It is the policy of the Laboratory to encourage publication in the open professional literature to the greatest possible extent.

In the past year, eighty-one internationally recognized scientific and technical periodicals have carried more than four hundred contributions from Argonne staff members in the basic physical and biological sciences and in engineering.

Staff positions are available both at the site near Chicago, Illinois and the site near Idaho Falls, Idaho for qualified *physical metallurgists, chemical engineers, physicists, mechanical engineers, metallurgical engineers, chemists, electrical engineers, mathematicians, technical writers.*

Argonne
NATIONAL LABORATORY

Operated by the University of Chicago under a contract with the United States Atomic Energy Commission

Direct inquiries to:
LOUIS A. TURNER, DEPUTY DIRECTOR
P.O. BOX 299-W5 • LEMONT, ILLINOIS

NUCLEAR SUPERHEAT

One of the advanced concepts that

GENERAL NUCLEAR ENGINEERING CORPORATION

is developing for construction in the ***immediate*** *future*

Graduate Engineers and Physicists with reactor design experience will find stimulating and rewarding opportunities in these boiling-superheating reactors, in gas-cooled reactors, and in other *practical* advanced concepts at General Nuclear.

Positions are also open for new graduates. Work in small design and development groups of broad scope gives maximum opportunity for advancement and for professional development.

Send resumes to: L. C. Furney
GENERAL NUCLEAR ENGINEERING CORPORATION
Dunedin, Florida

QUICK SOLUTION TO MANPOWER PROBLEMS

through the EMPLOYMENT OPPORTUNITIES Section of this publication. The market place for those offering or wanting the services of men on engineering, technical and executive level.

This section offers a quick effective solution to your manpower problems, because its readership is confined to just the type of men you need . . . Waste circulation is avoided . . . You reach only the men you want.

NUCLEONICS
P. O. Box 12,
New York 36, N. Y.

Accent Is On The Individual At ALCO . . .

A pioneer designer and manufacturer of nuclear thermal equipment provides many individual opportunities to qualified personnel. Liberal employee benefits including company assistance in furthering educational development at nearby universities. Current programs include the SM-1 operation and Core I loading, SM-1A and PM-2A final engineering and start-up, SM-2 design and development, and Core I procurement.

NUCLEAR ENGINEERS & PHYSICISTS

For small work group assignments within the Reactor Analysis Section

- To perform necessary calculations to establish core nuclear specifications.
- To perform necessary calculations to establish core cooling requirements.
- To perform necessary calculations to establish core shielding requirements.
- To develop and execute engineering programs for analog and digital computers.

College degree with several years' actual experience required.

SOME SUPERVISORY POSITIONS OPEN

Please send complete resume and salary requirements in confidence to: G. Y. Taylor, Administrative Services

ALCO **ALCO PRODUCTS** Incorporated
Schenectady 5, New York

Needed in the field of ATOMIC ENERGY

As contract operator for the Atomic Energy Commission, the National Lead Company of Ohio utilizes the latest technical equipment and technology to produce uranium fuel elements for use in nuclear reactors.

• METALLURGICAL ENGINEERS:

B.S., M.S. and Ph.D. degrees, with Metals Industry experience in foundry or fabrication technology—heat treating—metallography—physical testing —metals process control. Positions may involve assisting, planning, executing development projects in uranium.

• INDUSTRIAL HYGIENIST:

B.S. or M.S. degree in Health Physics, 5 to 7 years' experience in radiation and effluent control, planning projects and studies of conditions affecting the health of employees.

Please send resumé of education, experience and salary requirements to

EMPLOYMENT SUPERVISOR, Dept. J-101,

National Lead Company OF OHIO

P.O. Box 158, Cincinnati 39, Ohio

ENGINEERS—TECHNICIANS

In connection with our expanding activities in nuclear power, we have opportunities for qualified personnel in the following fields:

REACTOR SYSTEMS
—Engineers with experience in development and analysis of nuclear plant systems and components.

WATER CHEMISTRY
—Chemist with specialized experience in water quality control for reactor operations.

NUCLEAR PLANT TESTING
—Engineers or physicists with substantial test and start-up experience; marine application desirable.

REACTOR PHYSICS
—Physicist experienced in application of nuclear physics to design and test of nuclear reactors.

HEALTH PHYSICS
—Engineer or physicist with power reactor experience.

NUCLEAR INSTRUMENTATION
—Extensive experience on reactor control and radiation monitoring & instrumentation, including installation and maintenance. College degree not essential.

REACTOR OPERATIONS
—Experienced operators, preferably with experience in pressurized water plants, criticality and start-up operations; marine experience desirable, college degree not essential.

NEW YORK SHIPBUILDING CORPORATION
CAMDEN 1, NEW JERSEY

DO YOU NEED ENGINEERS OR TECHNICAL PERSONNEL WITH EXPERIENCE?

Place an "ENGINEERS WANTED" advertisement in this EMPLOYMENT OPPORTUNITIES SECTION of NUCLEONICS. It's an inexpensive, time saving method of selecting competent personnel for every engineering job in the nucleonics industry. The selective circulation of NUCLEONICS offers you an opportunity to choose the best qualified men available throughout the industry.

For Rates and Information Write:

CLASSIFIED ADVERTISING DIVISION

NUCLEONICS

P. O. Box 12
New York 36, N. Y.

REACTOR PHYSICIST

Salary to $12,555

Assume major role in planning and participation in staff technical direction of comprehensive research and development program in the field of reactor physics.

Position requires substantial general experience in physics research and specialized knowledge of the principles of nuclear and reactor theory.

REACTOR CONTAINMENT ENGINEER

Salary to $12,555

Assist in long-range planning of the domestic and related foreign reactor containment program through establishment and evaluation of programs relating to the accomplishment of economical and safe reactor containment.

Requires substantial experience in mechanical or structural engineering with emphasis in both mathematics and static and dynamic loading response of structures.

Relocation expenses paid.

Send resume to: Mr. A. W. Jackson
Office of Personnel
U. S. Atomic Energy Commission
Washington 25, D. C.

ORGANIC MODERATED REACTOR

12.5 Mw Piqua, Ohio

Chief Supervisor

Min. Requirements:—2 yrs. operation supervision in responsible supervisory capacity for a power, test or production reactor. 5 yrs. experience in an associated engineering field. Experience in a conventional steam plant desirable but not necessary.

Health Physicist

Min. Requirements:—Bachelor's degree in Physical or Biological Sciences or an applicable Engr. Degree. 3 yrs. experience in health physics field is required. Experience in safety and fire protection work desirable. Experience as a responsible health physicist in site survey activities and operational health physics controls of a large nuclear facility desired.

Mail resume and qualifications to:

J. P. Gallagher
Director of Utilities
Municipal Power Plant
Piqua, Ohio

RADIOLOGICAL SAFETY ENGINEER

UNIVERSITY OF CALIFORNIA, LOS ANGELES

Responsible for developing and administering the radiological safety program for the Engineering Nuclear Reactor and associated laboratories.

Training in the biological effects of ionizing radiation and in the principles of radiation hazards and protection is required.

Ability to communicate effectively and health physics experience with a reactor operating group are desirable.

This position offers opportunity for career advancement.

Write or apply to:

UNIVERSITY OF CALIFORNIA, LOS ANGELES
Employment Office
10833 Le Conte Avenue
Los Angeles 24, California

a challenge to

NUCLEAR ENGINEERS
PHYSICISTS
METALLURGISTS

Openings are immediately available for Nuclear Engineers, Physicists and Metallurgists interested in Applied Research, Development or Design of novel reactors at The Knolls Atomic Power Laboratory. The broad aim of these endeavors is to achieve a new regime of simplification in reactor technology.

U.S. Citizenship and appropriate scientific or engineering degree required.

Current Openings:

Ceramic Fuels
Computer Programming
Electrical Controls
Electronic Instrumentation
Heat Transfer/Fluid Flow
Mathematical Analysis
Physical Metallurgy
Plant Operation & Test
Primary Coolant Chemistry
Process Metallurgy
Reactor Physics
Reactor & Plant Design
Shielding Analysis
Solid State Physics
Stress Analysis

Address your inquiry to
Mr. A. J. Scipione, Dept. 48-MD.

Knolls Atomic Power Laboratory
OPERATED FOR A E C BY
GENERAL ELECTRIC
SCHENECTADY, NEW YORK

PROFESSIONAL PERSONNEL REQUISITION

NUCLEAR ENGINEERS — SCIENTISTS

The Nuclear Systems Division of The Marquardt Corporation, currently engaged in the development of a nuclear ramjet engine under Project Pluto, offers these outstanding opportunities for exceptionally qualified men:

NUCLEAR REACTOR PHYSICISTS

To solve analytical reactor physics problems and to apply transport and diffusion theory methods to specific reactor statics and dynamics problems. MS in Nuclear Engineering, Physics, plus applicable experience, required.

SHIELDING PHYSICIST

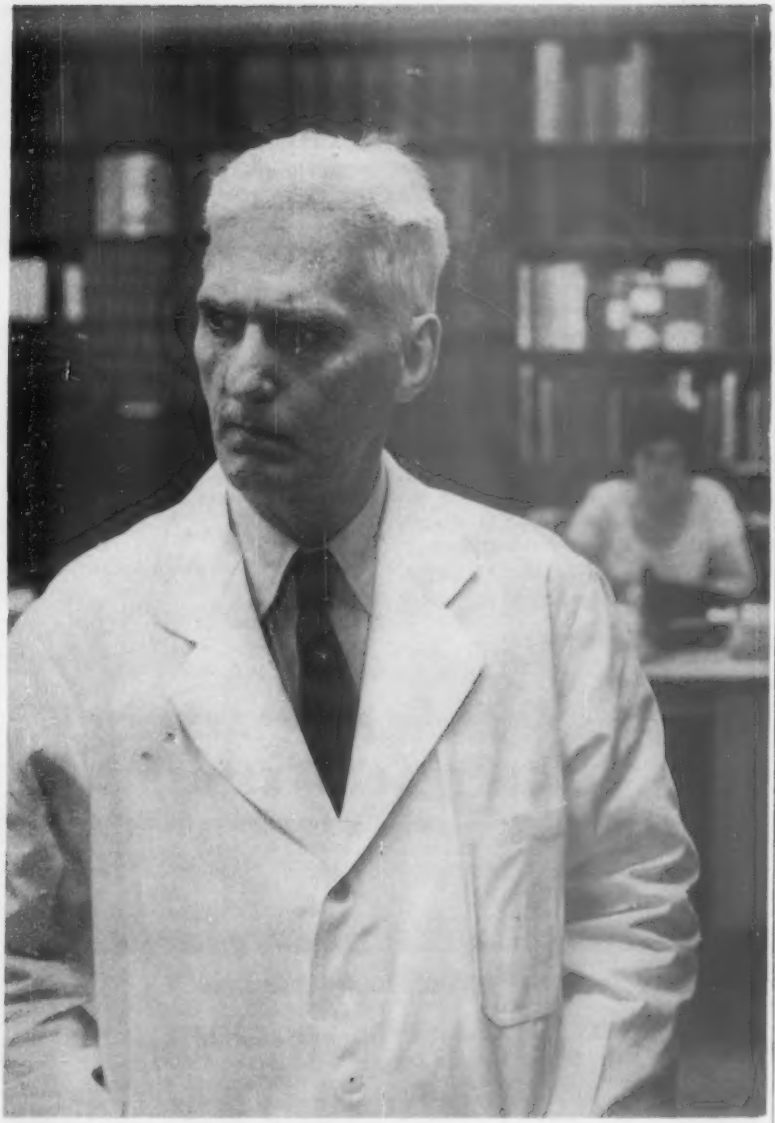
To perform radiation heating and shielding evaluations of advanced reactor systems. MS or Ph.D. in Nuclear Engineering, Physics, or applicable experience, required.

NUCLEAR ENGINEERS

To perform reactor physics calculations on advanced reactor systems, determine criticality criteria, flux and power distribution, reactivity coefficients, control systems, and nuclear parameters. MS in Nuclear Engineering or Physics or applicable experience required.

Send resume in confidence to:
Floyd Hargiss, Manager
Professional Personnel
16555 Saticoy Street
Van Nuys, California

THE Marquardt CORPORATION
Corporate offices: Van Nuys, California
Operations at: Monrovia, Pomona, Van Nuys, California — Ogden, Utah



"I need my own copy of NUCLEONICS each month," Dr. Dana says to himself. "I will subscribe today."

Yes, Dr. Dana is tired of going to the library to find other people have borrowed all the copies of NUCLEONICS.

And Dr. Dana is tired of being "low man on the routing list" — waiting for circulating copies to reach his desk.

Join Dr. Dana if you are engaged in nuclear work. Use the subscription card tipped into this issue and have NUCLEONICS available when and where you want it.

NUCLEONICS | A McGRAW-HILL PUBLICATION
330 West 42nd St., N.Y. 36, N.Y.

INDEX TO ADVERTISERS

APRIL 1960

Advertising Council 127
Alco Products, Inc. 9–12
Allis-Chalmers 45
American Smelting & Refining Company, Federated Metals Division 91
American Tradair Corp., Ekco Electronics, Ltd. 139
Anton Electronic Laboratories, Inc. 88
Atomic Energy of Canada Limited 13
Atomics International, A Division of North American Aviation, Inc. 55, 94, 95
Automatic Switch Co. 87
Babcock & Wilcox Company, Boiler Division 1
Bendix Aviation Corporation, Cincinnati Division 120
Brady Co., W. H. 111
Bristol Company, The 14
Brooks & Perkins, Inc. 112
Brush Beryllium Company 44
Budd Company, Space Atomics Division 46
Carboline Company 110
Carlson Inc., G. O. 103
Central Research Laboratories, Inc. 41
Central Scientific Co. 111
Charleston Rubber Company . . . 51
Columbia-Geneva Steel 42, 43
Cornell-Dubilier Electric Corporation 126
Corning Glass Works 148
Crawford Fitting Company 49
Crystals Division, Isotopes, Inc. . 131
Davison Chemical Division, W. R. Grace & Co. 85
Delta Chemical Works, Inc. 129
E.M.I. Electronics Limited 129
Eberline Instrument Corporation 111
Elcor, Inc. 130
Eldorado Electronics 92
Electronic Associates, Inc. 38
Falstrom Company 95
Flight Refueling, Inc. 99
Ford Instrument Co., Division of Sperry Rand Corporation . . . 119
Gaertner Scientific Corporation . 136
General Atomic Div. of General Dynamics Corp. 89
General Mills Nuclear Equipment Dept. 8
General Motors Research Laboratories 101
General Transistor Corporation 53, 54

Griscom-Russell Co. 18, 19
Hamner Electronics Co., Inc. 2nd Cover
High Voltage Engineering Corp. 107
Illinois Water Treatment Co. . . . 6
Instrumentation Associates 120
Joy Manufacturing Company . . 83
Kaiser Engineers 40
Keithley Instruments Inc. 34
Land-Air, Inc. 135
Landauer, Jr. & Co., R. S. 130
Landis & Gyr, Inc. 147
Landsverk Electrometer Company 15
Leeds & Northrup Co. 90
Librascope, Inc., A Division of General Precision, Inc. 104, 105
Lockheed Nuclear Products—Georgia Div. . . . . 3rd Cover
Los Alamos Scientific Laboratory 113
Mallinckrodt Nuclear Corporation 35
Martin Company, The 5
McGraw-Hill Book Company 36, 37
Michigan Chemical Corporation 138
Midwest Piping Company, Inc. . 47
National Carbon Company, Division of Union Carbide Corporation . . . . . 4th Cover
National Lead Company 58
Nuclear Development Corporation of America 20
Nuclear Enterprises Ltd. 134
Nuclear Measurements Corp. . . 86
Nucleonics 56, 57, 146
Paraplegics Mfg. Company, Inc. 129
Peerless Pump Division, Food Machinery & Chemical Corp. . 132
Picker X-Ray Corporation . . 93, 133
Pittsburgh Piping and Equipment Company 16
Radiation Counter Laboratories, Inc. 33
Radiation Instrument Co. 131
Radiation Instrument Development Laboratory, Inc. 109
Robertshaw-Fulton Controls Company, Fulton Sylphon Division 97
Rosemount Engineering Company 117
Searchlight Section 140–145
Smith Corporation, A. O. 48
Societe Electro Metallurgique Du Planet 147

NEW!

COMPACT ELECTRIC IMPULSE COUNTERS PRINT AS WELL AS INDICATE

SODECO Print Counters Provide Permanent Records

The new SODECO Print Counters offer all the accuracy and reliability of conventional SODECO counters with the added feature of a printing mechanism to provide a permanent record of the count at any given time.

SINGLE REGISTER: The compact, single register counters (measuring only 2⅞" x 5⅝" x 7 3/16") indicate pulse count to 6-digits and can be supplied with mechanical and electric zero reset. The count can be registered on the paper tape manually or by remote command.

DUPLEX MODELS: The left-hand register of the duplex model can be specified to indicate and print either date and time or an independent additional 6-digit count.

For complete technical information, write to:

LANDIS & GYR, Inc.

45 West 45th Street — New York 36, N. Y.

HIGH PURITY CALCIUM

for U Th and Pu metallurgy

cakes, lumps,
turnings, grains
average
impurities content:
Si 30 ppm
Al 20 ppm
N^2 20 ppm
Mn 10 ppm
Fe 5 ppm

χαλυβ χαλκεβ

Producer :

SOCIETE ELECTRO METALLURGIQUE DU PLANET

9, rue Chauchat, Paris 9e-France

Sales agents for Western Hemisphere

INTERNATIONAL SELLING CORP.

122 East 42nd Street, New York 17, N.Y.

Radiation Shielding windows give the Navy a direct look into nuclear reactors

In the Navy's new nuclear subs you'll find giant "peepholes"—windows that permit a *direct* look into the reactor compartments. Twelve of these atomic peepholes, weighing half a ton or more, have been ordered from C.G.W. by Westinghouse Electric Corporation for installation in the Navy's new sub fleet. Westinghouse designed and developed the nuclear reactors for the submarines under the direction of and in technical cooperation with the Naval Reactors Branch, U. S. Atomic Energy Commission.

These are weighty windows, made of Corning's high-lead-content glass and a plastic material. The latter shields against neutron bombardment; the high-density *glass* shields against gamma rays.

Round and encased in a metal housing, these radiation shielding windows are part of a complete line made by and available from Corning.

For details on types of glass, transmittance and shielding characteristics, darkening, and design considerations, ask for Bulletin PE-51, "Corning Radiation Shielding Windows."

Direct your inquiries to Corning Glass Works, 16 Crystal Street, Corning, N. Y.

CORNING GLASS WORKS

CORNING MEANS RESEARCH IN GLASS

Southern Lead Rolling Company 134
St. Gobain 132
Stromberg-Carlson, A Division of General Dynamics 17
Teleflex, Inc. 122, 123
Tennessee Coal & Iron 42, 43
Texas Instruments Incorporated, M&C Nuclear Inc. (a Subsidiary) 2
Texas Nuclear Corp. 140
United States Radium Corp. 121
United States Steel Corporation 42, 43
United States Steel Export Company 42, 43
Varian Associates 137
Victoreen Instrument Company. 7
Vitro Engineering Company, A Division of Vitro Corporation of America 52
Wade Products Company, Kenneth 132
Westinghouse Atomic Power Division 114
Westinghouse Electric Corporation, Atomic Fuel Dept. 125
Wheeler Mfg. Co., C. H. 18, 19
Wolverine Tube Division of Calumet & Hecla Inc. 39

PROFESSIONAL SERVICES 140

CLASSIFIED ADVERTISING
F. J. Eberle, Business Mgr.

EMPLOYMENT OPPORTUNITIES 140–145
Advanced Technology Laboratories, Div. of American Standard 141
Alco Products, Inc. 143
Argonne National Laboratory 142
Atomic Personnel, Inc. 140
California, University of 145
Esquire Personnel 140
Gallagher, J. P. 145
General Electric Company 145
General Nuclear Engineering Corp. 143
Internuclear Company 141
Lawrence Radiation Laboratory 140
Marquardt Corporation 145
Monarch Personnel 140
National Lead Company of Ohio 144
New York Shipbuilding Corp. 144
Piqua, City of Ohio 145
U. S. Atomic Energy Commission 145

This index is published as a service. Every care is taken to make it accurate, but NUCLEONICS assumes no responsibility for errors or omissions.

REACTOR DESIGN

—for power . . . process-heat . . . research . . . training

Lockheed's seasoned team of nuclear scientists and technicians is qualified to design and build nuclear reactors of any type—for every purpose.

A portable pool-type reactor is now being produced by Lockheed Nuclear Products for the Atomic Energy Commission. A 10 kw training reactor is being built for Ohio State University. And a cryogenic test loop is being produced for use in NASA's Plum Brook reactor.

Experience gained by LNP in the operation and management of America's largest nuclear radiation effects testing facility—the U.S. Air Force's Plant 67, on a 10,000-acre site at Dawsonville, Georgia—adds another significant dimension to our ability to design and build reactors to fulfill any defense, scientific, or commercial requirement.

A letter, wire or phone call will bring a Lockheed Nuclear Products representative to your plant or office to discuss your problems in:

- Reactor design and manufacture
- Facility design and operation
- Instrumentation
- Shielding
- Radiation effects
- Isotopes applications
- Hazards analysis

Write: Nuclear Sales Mgr., 3272 Peachtree St., N.E., Atlanta 5, Ga.

LOCKHEED

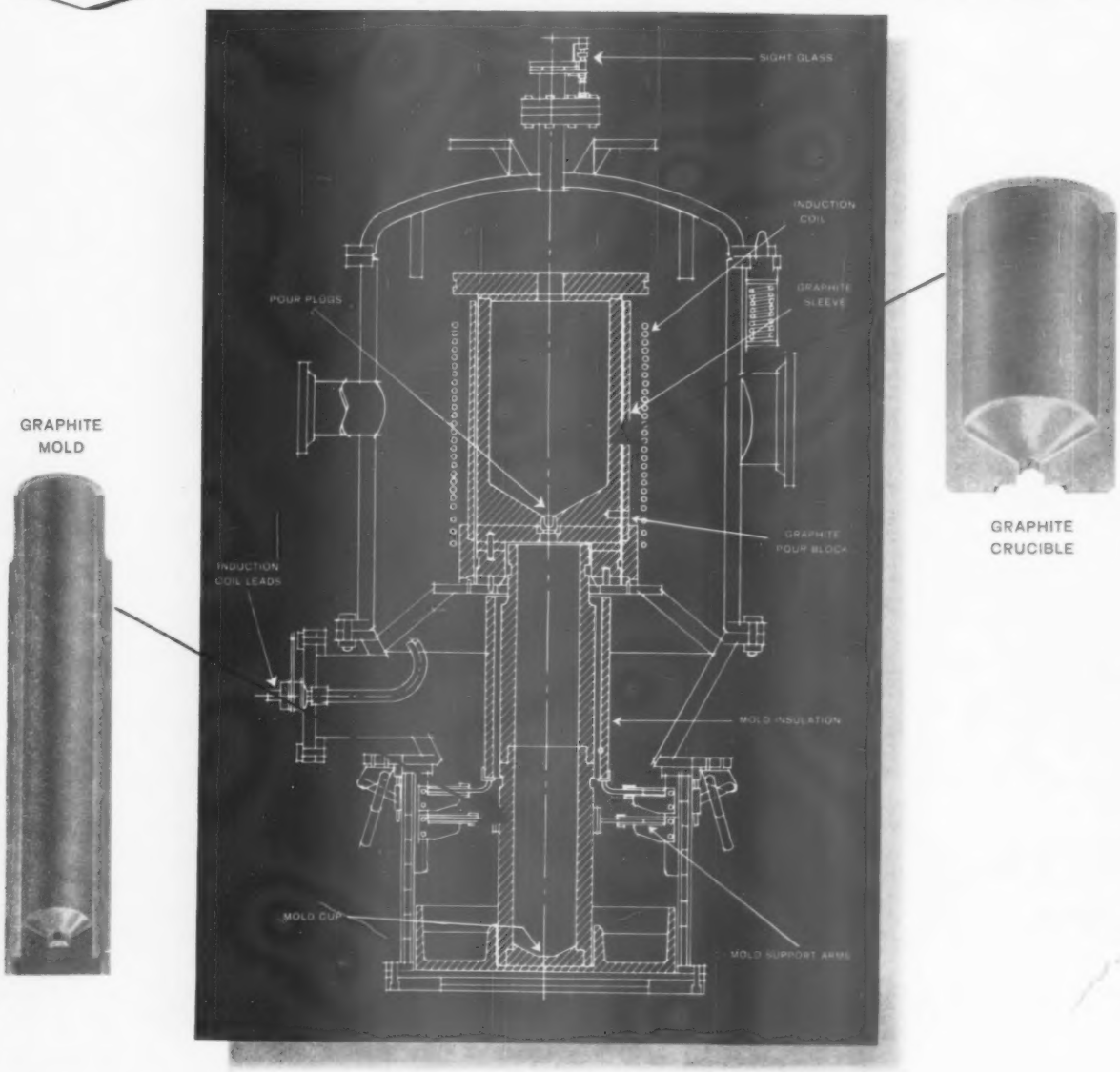
NUCLEAR PRODUCTS

GEORGIA DIVISION, LOCKHEED AIRCRAFT CORPORATION: DAWSONVILLE, MARIETTA, ATLANTA

OTHER LOCKHEED DIVISIONS: CALIFORNIA • MISSILES & SPACE • LOCKHEED ELECTRONICS CO. • LOCKHEED AIR TERMINAL • LOCKHEED AIRCRAFT SERVICE • LOCKHEED AIRCRAFT INTERNATIONAL • LOCKHEED, S.A. • PUGET SOUND BRIDGE AND DRY DOCK CO. **LOCKHEED PRODUCTS:** ELECTRONICS • MISSILES • AIRCRAFT • NUCLEONICS • SATELLITES AND SPACE VEHICLES • ROCKET FUELS AND MOTORS • AIRCRAFT MAINTENANCE • AIRPORT MANAGEMENT • SHIPBUILDING • HEAVY CONSTRUCTION

NATIONAL GRAPHITE MOLDS AND CRUCIBLES...

TRADE-MARK



FOR EFFICIENT AND ECONOMICAL PROCESSING OF A WIDE VARIETY OF METALS

"National" graphite molds and crucibles solve casting problems whether the process calls for handling ferrous, non-ferrous, exotic or precious metals. In many applications – such as the casting of uranium – graphite is the only material that will do the job.

Why? Because this material has good thermal conductivity and low thermal expansion. It has good strength at high temperatures and can be machined to precise tolerances. Where reactions which form excess carbides in the melt are likely to take place, various mold or crucible coatings can easily be applied on graphite. Also, carbon pickup can be inhibited with the use of properly designed parts. The electrical properties of graphite permit its use as a susceptor in induction melting; thus, the graphite mold or crucible may serve a dual function.

You'll save time and money when you specify "National" graphite molds and crucibles for your metal casting operations.

"National" and "Union Carbide" are registered trade-marks for products of

UNION CARBIDE

NATIONAL CARBON COMPANY • **Division of Union Carbide Corporation** • ***30 East 42nd Street, New York 17, N.Y.***

OFFICES: Birmingham, Chicago, Houston, Kansas City, Los Angeles, New York, Pittsburgh, San Francisco • **IN CANADA:** Union Carbide Canada Limited, Toronto